USEPA INTERNAL DRAFT
REMEDIAL INVESTIGATION REPORT

ALLIED PAPER/PORTAGE CREEK/KALAMAZOO RIVER
Kalamazoo, Michigan

Remedial Investigation / Feasibility Study

WA No. 134-RICO-059B / Contract No. 68-W6-0025

April 2003

SECTION 1

Introduction

The Allied Paper/Portage Creek/Kalamazoo River Superfund Site is located in southwestern Michigan. It encompasses roughly 80 river miles that include both free-flowing and impounded reaches of the Kalamazoo River. The Kalamazoo River generally flows northwest through the Superfund Site and ultimately discharges to Lake Michigan near Saugatuk, Michigan. The Superfund Site includes 5 disposal areas, 6 paper mill properties, the Kalamazoo River below Morrow Lake, the lower 3 miles of Portage Creek, a tributary of the Kalamazoo River, and also several landfills adjacent to the Kalamazoo River. The Superfund Site comprises five operable units (OUs):

- OU-1: Allied Paper Property/Bryant Mill Pond Area
- OU-2: Willow Boulevard site and A-Site
- OU-3: King Highway Landfill
- OU-4: 12th Street Landfill
- OU-5: Portage Creek and Kalamazoo River sediments (also "river operable unit")

1.1 Regulatory Background

On August 30, 1990, the Superfund Site was included on the National Priorities List. The primary contaminants of concern at the site are polychlorinated biphenyls (PCBs). PCBs exist in both the instream river sediments and the adjacent floodplain soils. The floodplain soils comprise, in large part, the sediments exposed as a result of the drawdown of impounded water levels behind the Plainwell, Otsego City, Otsego, and Trowbridge dams. Water levels were drawn down behind the Otsego City Dam in the 1960s. Water impounded by the Plainwell, Otsego, and Trowbridge dams was drawn down circa 1970. In 1985–86 the Michigan Department of Natural Resources (MDNR), the owner of the Plainwell, Otsego, and Trowbridge dams, removed the headworks in anticipation of their complete removal as a precursor to implementing its fisheries management plans and to increase safe public access to the river resources. The dams impound the river to the level of their remnant sills (roughly one-half the former impoundment levels). Of the three remnant impoundments, only the floodplain soils contained in the remnant impoundment of the Plainwell Dam is addressed in this report. The Otsego City Dam operated by the City of Otsego, also a subject of this report, was originally constructed to elevate river levels for commercial navigation; it has not been dismantled and continues to impound the river. The City of Otsego is in the process of planning and making repairs to the dam.

Since 1990, when the Superfund Site was listed on the National Priorities List, the Michigan Department of Environmental Quality (MDEQ) held the enforcement lead on the Superfund Site and entered into an agreement with a number of potentially responsible parties (PRPs) to conduct remedial investigation/feasibility study (RI/FS) work. In October 2000, the PRPs submitted draft RI and FS reports to the MDEQ and USEPA for review. In July 2001, the MDEQ announced that it would request the USEPA to take back, over time, the enforcement lead on OU-5 and certain other OUs associated with the Superfund Site, with the lead transition timing varying for each OU. In February 2002, the site-specific Memorandum of Agreement was revised and signed by both the MDEQ and USEPA defining the new roles.

1.2 Purpose

This RI report addresses the floodplain soils within two impounded reaches located within OU-5, designated the Plainwell and Otsego City impoundments (which will be referred to as the "site" in this report; Figure 1-1). The term "floodplain soils" as used in this report includes soils delineated as floodplain soils by the USEPA's Fully Integrated Environmental Location Decision Support (FIELDS) group during the removal assessment (Weston 2002) and the sediments that were exposed following the lowering of the impounded water behind the Otsego City Dam in the 1960s and the Plainwell Dam in the 1970s.

Previous reports have employed various terms to describe the nature and extent of contamination in similar and related environmental media: floodplain soils, riverbanks, and sediments exposed after the removal of the former dams and the drawdown of the water impounded behind them. To the extent that these environmental media fit the above definition of floodplain soils, they are included in this report; however, they are not considered individual media when describing the nature and extent of contamination.

This RI report consolidates existing information on the characteristics, distribution, and risk posed by the floodplain soils of the Plainwell and Otsego City impoundments. It will support an FS that evaluates alternatives to eliminate, reduce, or control risk to human health and the environment from the floodplain soils in the two impoundments that are part of OU-5. The goal of the RI and FS reports is to produce documents that will lead to the development of a well-supported Record of Decision (ROD).

1.3 Impoundment Descriptions

The physical characteristics of the Plainwell and Otsego City impoundment areas are summarized below based on information from the Blasland, Bouck & Lee RI report (BBL 2002) and others. Only the floodplain soils contained within the impoundments described below are characterized in this report.

1.3.1 Plainwell Impoundment

From Main Street in Plainwell to 1.9 miles downstream of the Plainwell Dam, the Kalamazoo River has an average width of about 197 feet and an average depth of about 3.7 feet (BBL 1994c). This reach includes the Plainwell Impoundment and the Plainwell Dam, a former hydroelectric facility that has been dismantled to the sill level. When operating, the dam had a head of 13 feet, and the impounded water covered an area of 123 acres (Miller 1966). The sill of the dam has a head of about 5 feet (Johnson et al. 1989) and an impounded surface area of about 44 acres. The drainage area around the impoundment covers 1,299 square miles (Hayes 1996b). Part of the impounded area now lies above the water line. The exposed area is covered with old sediments and has since been vegetated. The reach is located in both Gun Plain and Otsego townships. According to the MDNR, impoundment stages higher than an elevation of 707.0 feet above mean sea level will result in water flowing over parts of the embankment adjacent to the spillway and the former powerhouse. Spillway capacity at an elevation of 707 feet is about 5,700 cubic feet per second (cfs), which approximates the 10-year flood stage (Hayes 1996b).

1.3.2 Otsego City Impoundment

The 1.7 miles of the river between the Plainwell to Otsego City dams covers 96 acres at an average width of about 450 feet and average depth of about 2.5 feet (BBL 1994c). For the most part, this reach comprises the Otsego City impoundment in Otsego Township. The impoundment contains large amounts of silt, and the adjacent shoreline is characterized by swampy, marshy conditions (NUS 1986). The Otsego City Dam impounds water at an elevation of 699 feet above mean sea level (United States Geological Survey [USGS] 1973). The dam has a head of about 8.5 feet and impounds 500 acre-feet of water.

1.4 Approach and Report Organization

This report is a compilation and summary of previous datasets and reports or parts thereof relating to the floodplain soils of the Plainwell and Otsego City impoundment areas. Because of the extensive body of work available for the river in general and the two impoundments in particular, a new field investigation was not undertaken, nor was a separate risk assessment performed. As such, this report relies on existing datasets and reports to evaluate the floodplain soils of the Plainwell and Otsego City impoundment areas. The evaluation of the existing data serves as the basis for the RI and FS.

This report is organized as follows:

- **Section 1, Introduction**.
- **Section 2, Previous Investigations,** documents the existing body of work for the site and calls attention to recent removal assessment work specific to the Plainwell and Otsego City impoundment areas.
- **Section 3, Physical Site Description,** documents the topography, weather, soil and geology, surface water and groundwater hydrology, demography, land use, and ecological characteristics of the Site.
- **Section 4, Nature and Extent of Contamination,** provides an assessment of the extent to which the floodplain soils of the Plainwell and Otsego City impoundment areas are contaminated with PCBs.
- **Section 5, Contaminant Fate and Transport,** provides an assessment of the mechanisms affecting the presence and movement of PCBs from the floodplain soils at the impoundments into the river, including erosion of floodplain soils, and an assessment of the effects of dam removal. It also discusses potential data gaps pertaining to PCB transport, such as transport from groundwater to surface water.
- **Section 6, Remediation Goals,** summarizes the results of previously performed human health and ecological risk assessments, and presents results in the context of the Plainwell and Otsego City impoundments.

- **Section 7, Summary,** presents the significant findings of work to date as they apply to the remediation of exposed contaminated sediments in the Plainwell and Otsego City impoundment areas.
- **Section 8, References,** lists the reports or other references cited in this report.

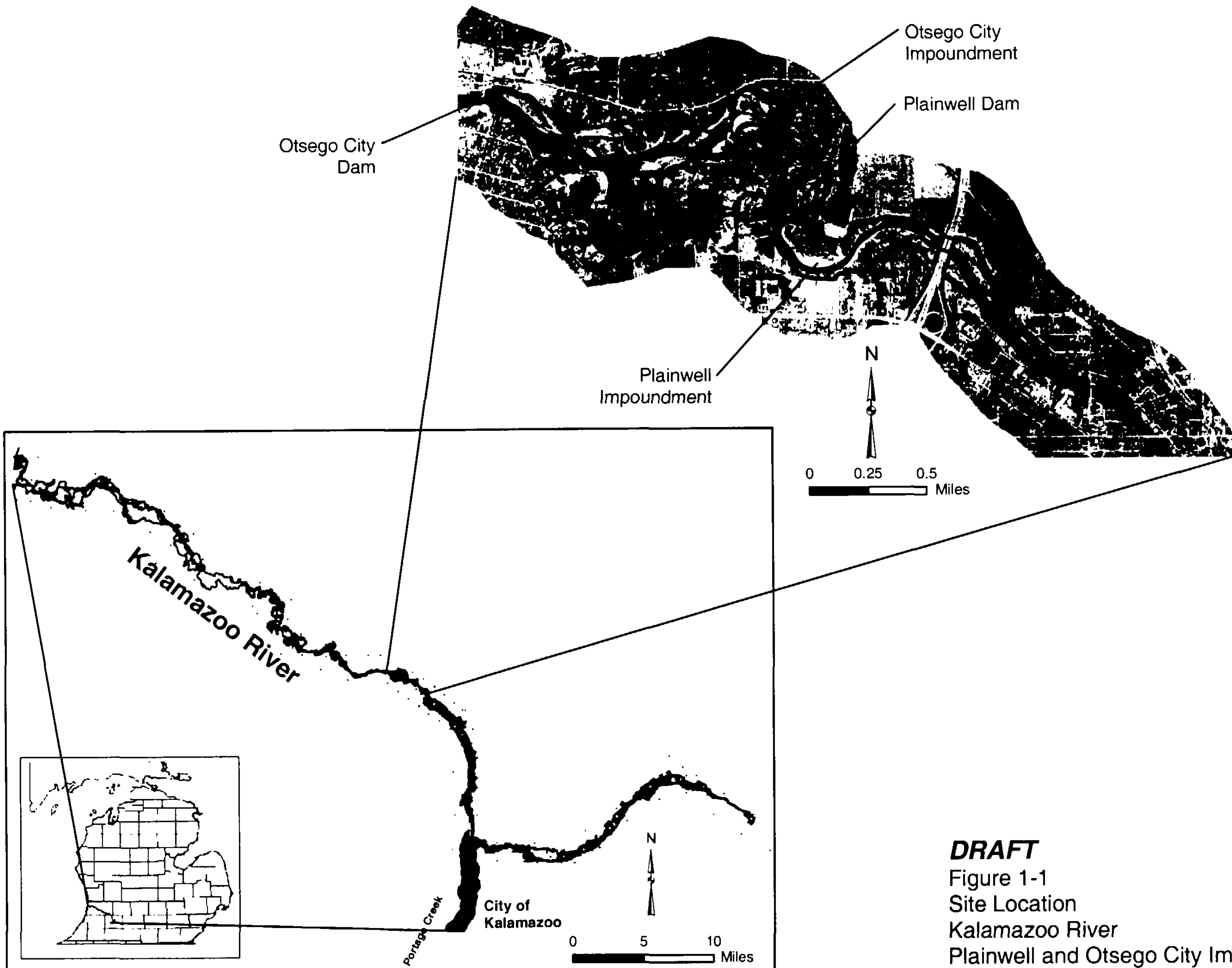

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Figure 1-1
Site Location
Kalamazoo River
Plainwell and Otsego City Impoundments

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SECTION 2

Previous Investigations

This section gives a brief overview of some of the studies performed in the last 10 years of the PCB contamination at the Allied Paper/Portage Creek/Kalamazoo River Superfund Site. The studies discussed pertain to OU-4 and OU-5 and deal with instream and outstream PCB releases and remediation. Where possible, the focus is on work performed at or near the Plainwell and Otsego City impoundments within OU-5. Other work discussed is of a general nature but still applicable to the site as a whole. The references consulted were compiled from both documents in hand as well as a USGS bibliography of select works. Materials considered were based on the nature of investigations performed, geographic location, and type of PCB contamination. The information provided is meant to give the reader background of the type of work already performed at the Kalamazoo River/Portage Creek Superfund Site. Table 2-1 summarizes the works described in this section.

2.1 1992: BBL Areas of Concern Report

In July 1992, Blasland, Bouck, & Lee, Inc. (BBL), prepared a report identifying areas at the site to be addressed in a future RI. The presence of PCBs was deemed of primary concern. The report described current activities within the RI areas and provided an estimate of the annual transport of PCBs from the Kalamazoo River to Lake Michigan (BBL 1992).

2.2 1993–1995: Envirogen Bioremediation Pilot Tests

In November 1993, Envirogen, Inc., submitted a proposal to BBL regarding the possibility of using biological treatment methods to remediate PCB-laden sediments in a small pond. Envirogen's research showed that bioremediation could be considered as a first treatment option (Envirogen 1993). Envirogen's final report in April 1995 stated that after using three different test bioremediation conditions, aerobic biotreatment proved to be the most effective in lowering PCB levels in submerged sediments. PCB concentrations dropped from 17.9 mg/kg to 5.5 mg/kg in the river and from 271 mg/kg to 130 mg/kg in the test pond (Envirogen 1995).

2.3 1994: BBL Additional Sources Studies

The Menasha Corporation and Rock-Tenn Company are located along the banks of the Kalamazoo River in Otsego. Both were the subject of case studies of PRPs performed by BBL in May 1994. In both cases, PCBs were detected in wastewater effluent or noncontact cooling water. Both organizations are documented users of PCBs and have discharged PCBs directly into the river. BBL's reports describe current operations at these facilities (BBL 1994a, 1994b).

2.4 1994–1996: Geraghty & Miller 12th St. Landfill and Plainwell Paper Co. RI Reports

Geraghty & Miller, Inc., performed an RI at the 12th Street Landfill (OU-4; adjacent to the Otsego City impoundment and just downstream of the Plainwell impoundment) in May 1994 to ascertain the nature and extent of contamination (Geraghty & Miller 1994). Hydrogeologic tests were performed, monitoring wells installed, groundwater samples taken, and soil borings drilled. The results of the RI were presented in a report in March 1996. Groundwater samples analyzed did not contain detectable concentrations of PCBs, but one of three leachate samples contained 0.0014 ppm of PCB (Geraghty & Miller 1996a). The Simpson Plainwell Paper Company had Geraghty and Miller perform an RI on its behalf in December 1996. The RI report summarizes the work conducted, and the analytical results of the RI were then used to evaluate PCB fate and transport (Geraghty & Miller 1996b).

2.5 2000: BBL Kalamazoo River / Portage Creek RI/FS

In October 2000, BBL conducted an RI and an FS of the Kalamazoo River/Portage Creek. The focus was on the Kalamazoo River between the Morrow Dam and the Lake Allegan Dam and also 3 miles of Portage Creek. The Plainwell and Otsego City impoundments are within that segment of the river. The RI characterized the site's actual and potential hazards by attempting to determine the sources of contamination along the river, the extent of contamination, and the migration and movement of the PCBs. The conclusions drawn from the data collectedwere that PCB contamination is widespread throughout the site, and there are no specific locations of extremely high PCB concentrations (i.e., no hotspots). The study also found that no significant contamination of floodplain soils had occurred and that, in general, the last 2 decades have shown declines in the levels of PCB transport and bioavailability, which were attributed to the effects of natural attenuation. The report concluded that the most significant source of PCBs to the Superfund Site was the eroding banks near the former dam impoundments (BBL 2000a).

The RI report stated that there are no areas of extremely high PCB concentrations, and thus the entire site must be considered when determining remedial actions for the FS. The basis for developing a general response action was a baseline human health assessment and an ecological risk assessment. The alternatives identified for a general response action included no further action, source control, institutional controls and monitoring, monitored natural attenuation, in-place containment, hydraulic modification, sediment treatment, sediment removal, sediment dewatering, sediment disposal, residuals management, and fisheries management. Areas deemed a priority for remediation were the banks adjacent to the MDNR's former impoundments. This determination was made on the basis that a reduction of PCB loading from the banks will result in the greatest downstream reduction of PCB levels. After evaluation and comparative analysis of potential remedial alternatives, remediation technique considered to be most effective, feasible, and easily implemented was stabilization of the river banks near the former dam impoundments. This preferred remedial action would include closely monitoring natural attenuation and implementing institutional controls (BBL 2000b).

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TABLE 2-1
Kalamazoo River RI/FS References

Reference Title	Date Published	Application to "Impoundment Soil" Sites: Instream	Application to "Impoundment Soil" Sites: Outstream	Location: Plainwell	Location: Otsego City	PCBs?: Releases	PCBs?: Remediation	Brief Description of Study	Type of Study: General	Type of Study: Site-Specific
PRP Group; Blasland, Bouck, & Lee, Inc., Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site- Description of the current situation, V1,2,6,7	July 1992	x	x			x		This report aids in the identification of specific areas to be included in an RI. Estimates annual transport of PCBs from the Kalamazoo River to Lake Michigan.	x	
Envirogen, Inc.; Statement of Proposal to Blasland and Bouck Engineers, P.C. for PCB Biodegradation Treatability Studies.	Nov 1993		x				x	Blasland and Bouck Engineers are interested in determing whether biological treatment methods could bioremediate PCB-containing sediments in a small pond. According to Envirogen, bioremediation is considered a first treatment option. Proposal also discusses laboratory biotreatability testing, PCB analysis, and results.	x	
PRP Group; Blasland, Bouck & Lee, Inc, Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site: PRP Case Study: Menasha Corporation, Otsego, Michigan	May 1994				x	x		Description of the Menasha Corporation in Otsego, Michigan. PCBs detected in the Menasha Corporation's effluent are investigated, as they are a documented user of PCBs.		x
PRP Group; Blasland, Bouck & Lee, Inc., Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site: PRP Case Study: Rock-Tenn Company, Otsego, Michigan	May 1994				x	x		PCBs were detected in the Rock-Tenn Company's treated wastewater and noncontact cooling water. Outfall monitoring data document PCB discharges to the Kalamazoo River.		x
MDEQ; Geraghty & Miller, Inc.,Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site remedial investigation/feasibility study: 12th Street Landfill Operable Unit; Plainwell, Michigan, Technical Memorandum 8, Volume I	May 1994		x	x				RI conducted to assess the nature and extent of contamination in the 12th St. landfill. Soil borings were drilled and monitoring wells installed. Hydraulic conductivity of the surficial aquifer also was determined.		x
Envirogen, Inc., Report to Blasland, Bouck, & Lee: Evaluation of Bioremediation Treatment of River and Pond Samples for PCB Reduction at a Site in Kalamazoo, Michigan: Final Report	April 1995		x				x	Final report of the 1993 Blasland and Bouck proposal to biodegrade PCB-sediments in a small pond. After three test conditions, bioaugmentation (aerobic biotreatment) proved to be the most effective in lowering PCB levels.	x	
MDEQ; Geraghty & Miller, Inc., Remedial Investigation Addendum I: 12th Street Landfill Operable Unit Plainwell, Michigan: Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site	March 1996		x	x				Report discusses methods and findings of the groundwater sampling conducted at the 12th Street landfill. Describes the 1st RI conducted of the site in September 1993. Initially, groundwater and leachate were analyzed for PCBs at the Contract Required Quantitation Limit of 0.001 mg/L. After reviewing the data, the MDEQ raised concerns that PCBs may be present at concentrations between 0.001 and 0.002 mg/L. Another sampling round was conducted with a TMDL of 0.0002 mg/L. PCBs were not detected in unfiltered samples of groundwater. Aroclor-1242 was detected in 1 of 3 leachate samples (0.0014 mg/L)		x
Simpson Plainwell Paper Company; Geraghty & Miller, Inc., Remedial Investigation Report: 12th Street Landfill Operable Unit Plainwell, Michigan: Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site	Dec 1996		x	x				RI report describes investigations conducted at the 12th St. landfill. Summarizes the investigative activities and reports the findings. The results are used to evaluate the fate and transport processes for PCBs.		x

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TABLE 2-1
Kalamazoo River RI/FS References

Reference Title	Date Published	Application to "Impoundment Soil" Sites: Instream	Outstream	Location: Plainwell	Otsego City	PCBs?: Releases	Remediation	Brief Description of Study	Type of Study: General	Site-Specific
PRP Group; Blasland, Bouck, & Lee, Inc., Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site RI/FS: Remedial Investigation Report- Phase I (draft document)	Oct 2000	x	x	x	x		x	The RI characterizes the site's actual and potential hazards to public health and the environment by determining contaminant sources, extent of contamination, and movement and migration pathways of PCBs. Conclusions drawn from data collected and previous studies show that: PCB contamination generally is widespread throughout the region, with no areas of extremely high PCB concentration; no significant contamination has occurred on the floodplain regions adjacent to the river; the past 2 decades have shown declines in the levels of PCB transport and bioavailability, largely due to natural attenuation; a conceptual model shows continuing reduction in bioavailable PCB; the most significant active source of PCBs to the river are the eroding banks of exposed sediment near the 3 former dam impoundments.	x	
PRP Group; Blasland, Bouck, & Lee, Inc., Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site RI/FS: Feasibility Study Report- Phase I (draft document)	Oct 2000	x	x	x	x		x	The FS determined sites to be remediated, potential methods of remediation, and a comparitive anaylsis between methods. The area of primary focus (Phase I) is the river reach between Morrow and Lake Allegan dams (Otsego and Plainwell sites lie in reaches B, C, and D of Phase I). The report concludes that the preferred remedial action for contaminated sites is to stabilize the banks near the former dam impoundments, closely monitor natural attenuation, and implement institutional controls.	x	
PRP Group; Blasland, Bouck, and Lee, Inc., Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site Kalamazoo & Allegan Counties, Michigan. PCB in the Kalamazoo River: Update for Decision Makers- Latest Findings for Sediment, Surface Water, and Fish	Aug 2001	x	x					The document describes the most recent findings obtained in 1999, 2000, and 2001. It confirms that natural attenuation is active in the Kalamazoo River and can be attributed to the PCB reductions observed; eroding river banks in former impoundments are an active source of PCB to the river; investigations by the MDEQ and USEPA of the ArvinMeritor, Inc. facility show the existance of ongoing uncontrolled sources of PCB to the Kalamazoo River, thereby decreasing the rate of natural attenuation.	x	
MDEQ; Quantitative Environmental Analysis, LLC. Hydro-Period Analysis for the Kalamazoo River	Aug 2001		x	x	x			This report determines hydroperiods for the floodplain areas of the Kalamazoo River from Morrow Lake Dam to Lake Allegan Dam. The study used a 1-dimensional hydraulic model (HEC-6), measured bank heights, and topographic maps to calculate the bank-full flow rate, the overbank flow frequency, hydroperiod length, and floodplain inundation extent. Assumptions and data gaps aside, this study provides a good approximation of hydroperiod duration and extent.		
MDEQ; US Geological Survey: Water Resources Investigations Report 02-4098): Sediment characteristics and configuration within three dam impoundments on the Kalamazoo River, Michigan, 2000.	2002	x		x	x			The report describes the data collection performed by the USGS in an effort to ascertain the volume, character, and size distribution of instream sediments around and between dam impoundments at Plainwell, Otsego, and Allegan. Data collection primarily consists of sediment cores taken at numerous transects across the Kalamazoo River. Sediment-depth profiles and particle-size analyses also were used. The data were used to determine the configuration of the present-day and pre-dam stream channels.		x
USEPA; Roy F. Weston, Inc.: Removal Assessment Report for Allied Paper- Kalamazoo River Site Otsego/Plainwell, Michigan	Feb 2002	x	x	x	x		x	The report was meant to provides more accurate analytical data for modeling the extent of PCB contaminated sedimentss and soils. Objectives were to obtain a better understanding of PCBs and dioxins in the Kalamazoo River's sediments and soils, to refine the estimated volume of sediment that must be removed from the assessment area, and to determine the delineation and extent of contamination of sediments, exposed sediments, and floodplain soils. Data collected will allow comparison with 1994 sampling .		x

2.6 2001: BBL RI/FS Supplement

In August 2001, BBL produced a supplement to its RI/FS. The document was designed to update those involved with the site with the most recent information gathered. In summary, the report concludes that natural attenuation is occurring and is the reason PCB reductions have been observed. It reiterates that the erosion of riverbank sediment near the impoundments is an active source of PCB contamination in the river (BBL 2001).

2.7 2001: QEA Hydroperiod Analysis

The MDEQ tasked QEA (Quantitative Environmental Analysis, LLC) to determine the duration and extent of inundation (hydroperiod) on floodplain soils along the Kalamazoo River. Determination of hydroperiods in the impoundment areas is important, as inundation can remobilize the PCBs contained in the floodplain soils and influence geomorphic processes along the river. Transect data from a sediment survey (of bank heights), dam rating curves, flow and stage records (1984–93) from USGS river gauging stations at Comstock and Fennville, and topographic maps provided the necessary inputs for the hydraulic model (HEC-6) used. It should be noted that bank height data used in the model were interpolated between transect locations, and that hydroperiods were calculated only for the years 1984 to 1993 (limited concurrent gauging station data) (QEA 2001). Flow calculations input to the model to account for the discharge contributed to the main channel from tributaries are likely to be flawed, as groundwater seepage to or from the Kalamazoo River channel was not considered or easily quantified. The modeling effort did not consider the storage of rising water on the streambanks or use of functional dams upstream to regulate flow. Thus, inundation time and extent should be considered as conservative estimates.

The model approximated bank-full flow rates, overbank flow frequency, hydroperiod duration, and areal extent of flooding in each impoundment area between Morrow Lake and Lake Allegan, including the Plainwell and Otsego City impoundments. Areal extent of flooding was determined by using topographic maps with 5-foot contour intervals and modeled stage heights. The lack of elevation detail on the maps led to some uncertainty in the delineation of flooding extent. Sensitivity analyses showed the bank-full flow rate and hydroperiod to be predictably sensitive to changes in the model's roughness coefficient and bank height (QEA 2001). Although there are several flaws in the hydroperiod determination methodology, QEA's results provide a reasonable picture of flooding at the impoundment areas.

2.8 2000–2002: USGS / MDEQ Sediment Configuration at Impoundments

The USGS and MDEQ prepared a report in 2002 to define the Kalamazoo River's fluvial sedimentology within the Plainwell, Otsego, and Trowbridge impoundments. The object of the report was to provide a better estimate of the volume, configuration, character, and distribution of instream sediments at the impoundments. This was accomplished by taking sediment cores at numerous transects of the river. The project included creating sediment-depth profiles and performing particle-size analyses from the cores. The sediment cores provided information on both pre- and post-impoundment erosion and deposition. Lacustrine deposits accumulated when the dams were in place. The fine-grained deposits range in thickness from zero to 12 feet. Alluvial deposits accumulated on the erosional cut into the lacustrine deposits, once the dam superstructures were removed. These coarser deposits range in thickness from zero to 5.5 feet. The data obtained were used to prepare a series of detailed isopach maps for each impoundment area, before and after the dismantling of the dams. It is estimated that the complete removal of the impoundments would increase the slope of the river to more than 2 percent, making the river a moderate-gradient system (USGS 2002).

2.9 2002: Weston Floodplain Soil and Sediment Sampling

In February 2002, Roy F. Weston, Inc., conducted a removal assessment of the site on behalf of the USEPA in an effort to provide more accurate analytical data for modeling the extent of PCB-contaminated soils and sediments. Soil and sediment samples were collected in two phases. During Phase I, samples were obtained along the Kalamazoo River and its adjacent floodplains between Plainwell to Otsego. In Phase II, samples were obtained in a radial grid pattern around specific samples from Phase I. This was done to provide greater resolution in determining the extent of contamination. The study found that Aroclor-1242 is the most common PCB at the site and that most of the PCB contamination is within the uppermost 2 feet of sediment or soil (Weston 2002).

SECTION 3

Physical Site Description

The Plainwell and Otsego City impoundment areas within OU-5, lie in and along the Kalamazoo River. The area has been considerably altered by dams constructed to take advantage of the increased river gradient along this segment of river. The dams created manmade depositional basins, causing PCB-contaminated sediment to accumulate upstream of them. The impoundment areas behind several dams were drawn down in the 1960s and 1970s. This increased the river's velocity, causing it to erode a channel into the deposits that had accumulated behind the dams (BBL 2000b). In 1987 the MDNR partially removed the Trowbridge, Plainwell, and Otsego dams. This action created instability in the adjacent river banks and accelerated their erosion. The dam foundations still remain and retain a large quantity of upstream PCB-laden sediment. The natural river channel is not yet restored, as the dam sills still maintain a hydraulic head of about 5 to 10 feet (Weston 2002). The physical characteristics of the area in part control the instream and outstream fate and transport of PCB. This section gives a descriptive overview of the site's geographic, geologic, and hydrologic settings to provide a governing background for PCB fate and transport.

3.1 Geography and Geology

The Allied Paper/Portage Creek/Kalamazoo River Superfund Site lies within the Great Lakes Basin in the Kalamazoo River watershed of Michigan's lower peninsula. The watershed drains 2,020 square miles of southwest Michigan in 10 counties. The watershed reaches 162 miles into south-central Michigan and ranges in width from 11 to 29 miles. The main river channel flows northwest for 123 miles before emptying into Lake Michigan (KRWPAC 1998; BBL 2000b; see Figure 1-1).

The Kalamazoo River consists of several free-flowing sections separated by dam impoundments and partially removed dam impoundments. The area of primary focus for the RI—the Plainwell and Otsego City impoundments—accounts for part of the impounded areas along the river. The cities of Plainwell and Otsego are located in southeast Allegan County along the Kalamazoo River. From Plainwell, the river meanders northwest through Allegan County past the cities of Otsego and Allegan before it eventually drains into Lake Michigan near Saugatuk, about 40 miles downstream of Plainwell. The river gradient between Plainwell and Allegan increases to 2.6 feet per mile, hence the construction of several dams in this region (KRWPAC 1998). Between the remnants of the Plainwell and Otsego dams, there are numerous sand/silt bars and multiple channels, making the river braided in that segment (BBL 2000b).

The physical geography of the area is largely a result of recent glaciation. In the late Pleistocene Epoch, during the Wisconsinan glacial stage (15,000 to 17,000 years ago), the region was an interlobate area between the Michigan and Saginaw glacial lobes. Meltwater from the lobes drained away in a massive river channel that carved out much of the modern Kalamazoo River valley. With continued climatic warming, the glacial lobes withdrew to the north and west. Outwash sands and gravel deposits (the Galesburg-Vicksburg outwash plain) all along the modern Kalamazoo River basin were a result. Broken ridges of cobbly sand and gravel mark the extent of this former drainage channel. The nonuniform nature of glacial retreat left deposits of sandy till and massive to poorly bedded cobbly sand with lenses of sandy clay to form the Kalamazoo Moraine, a large and continuous ridge of glacial till. This moraine is one of southern Michigan's most prominent glacial features. As the glacial lobes continued to retreat, the present drainage pattern developed, allowing meltwater to flow northwest out of the Kalamazoo River valley. The area's glacial deposits can vary in thickness from 50 to 200 feet atop the Coldwater shale, the regional bedrock unit laid down during the Mississippian Period (320 to 345 million years ago). The shale is more than 500 feet thick and dips underneath the Michigan Basin to the northeast (Rheaume 1990; Levertt and Taylor 1915; Monaghan and Larsen 1984). With no other significant geomorphic activity since the glacial retreat at the close of the Wisconsinan Stage, the landscape remains much as it has been for more than 10,000 years, and the river has shifted channels and meandered in the same river valley. The only significant deposition along the river valley is the thin floodplain deposits.

With topography influenced largely by past glacial activity, the area is relatively flat with gentle rolling plains. In general, the land surface slopes gently westward toward Lake Michigan. Ground and terminal moraines, eskers, and drumlins provide the only significant relief over the region. Low elevation areas are typically wetlands or bodies of open water, such as kettle lakes. The drainage patterns present are centered around the former meltwater drainageway, which is now, at its lowest points, occupied by the Kalamazoo River. The river itself drops 540 feet in elevation from its headwaters to its mouth, producing a slow to moderate stream gradient (KRWPAC 1998).

The topography of the Plainwell impoundment area is very much a reflection of the bathymetry of the river before the dam's removal. The river has two large meander bends that run about a mile upstream of the reduced dam. The insides of the meander bends are wide and flat with only 1 to 3 feet of relief. These areas mark the primary location of deposition when the river was fully impounded. The outer banks of the meander bends are steep, with 10 to 25 feet of relief. In some areas of the outer banks, there are small, flat areas 10 to 50 feet wide. These, too, are depositional relics of the former impoundment water levels and have the greatest potential for erosion, as they border the eroding bank of the river channel. Upstream of the meander bends, the river straightens its channel somewhat and has wide, impoundment-deposited flats on each side of the river. In areas where the depositional flats are not present, the banks are steep, with 10 to 15 feet of relief.

The river channel between the Plainwell impoundment area and the Otsego City dam changes from meandering to braided, and so the topography too is somewhat different. Interspersed throughout the river channel are large bars and islands of low relief (less than 5 feet). Extending laterally away from the river are low relief flats (0 to 10 feet). The transitory nature of a braided river channel makes its features wide and level, as the river constantly changes its path, eroding and depositing in new areas.

Soils that developed in the glacial deposits since the Wisconsinan Stage vary, ranging from clay and silt to sand and organic material. The soils in Allegan County are primarily sandy loams with minor areas of clay, clay loams, or organic soil. Organic soils tend to occur in river bottoms (KRWPAC 1998). Soil found in the impoundment areas are sediments that accumulated before the water levels were drawn down. These soils are generally level, poorly drained, and often flooded. At Plainwell, the soil is a mix of silt loam, ponded aquents and histosols, and loamy sand. Soil at the Otsego impoundment is mostly silt loam. The floodplain soils that accumulated are thin, at most only 2 feet deep. They have a high organic content and are generally very fine-grained (BBL 2000b).

When the Plainwell, Otsego, and Trowbridge dams were taken down to their sill levels in 1987, the resultant drawdown of 5 to 10 feet increased the river's flow velocity and exposed floodplain soils that formerly were inundated. The sediments previously deposited by the stagnant river in the exposed areas are very fine-grained. The extent of the floodplain soils can be seen inside the delineation of the field study area shown on Figure 3-1. Because of their exposure, floodplain soils with high concentrations of PCBs have become highly susceptible to mobilization downstream. The floodplain soils at the Plainwell impoundment were on average about 3.8 feet deep, being thickest directly behind the dam sill. Typically a few inches of silty to sandy organic soil cover the fluvial sediments. Exposed floodplain soils at the Otsego impoundment averaged 4.4 feet in thickness and deposits bordering the river channel had bands of a gray clay (BBL 2000b). Figure 3-2 shows the floodplain soil thickness across the area in greater detail.

3.2 Meteorology

Southwestern Michigan has a temperate climate, with four definite seasons. The Plainwell and Otsego City impoundments are too far inland from Lake Michigan to feel any significant temperature buffering effects. The Kalamazoo River watershed's average temperature is 72°F in July and 24°F in January (KRWPAC 1998). Allegan, roughly 10 miles northwest of the Plainwell and Otsego City impoundments, has an annual maximum mean temperature of 58.6°F and annual minimum mean of 38.0°F. The annual mean precipitation in Allegan is 35.6 inches per year, including 78.4 inches of snow (National Climatic Data Center 1951–80).

3.3 Hydrology and Hydrogeology

The Kalamazoo River watershed has roughly 400 miles of tributaries as part of the Great Lakes Basin that ultimately feed into the Atlantic Ocean. There are some 2,450 lakes and ponds spread throughout the watershed. The main branch of the Kalamazoo River, which flows through the OU-5 impoundments, forms upstream at the confluence of the smaller north and south branches in Albion. A combination of free-flowing and impounded segments, the Kalamazoo River has areas of swift-moving open water and standing backwater. The free-flowing reaches often have multiple channels, sandbars, and meanders. These features are dictated by heterogenous distribution of glacial sediments the river flows over as well as the river's flow rate (BBL 2000b; KRWPAC 1998; Weston 2002).

Long-term stream gauging records kept by the USGS at several locations along the Kalamazoo River show that flow generally has been stable over time. Typically, the highest flow rates occur in March and April, resulting from snowmelt and seasonal rainfall. The lowest flow rates tend to occur in August or September, because soil infiltration and evapotranspiration are at their highest. The Comstock (upstream) and Fennville (downstream) gauging stations kept discharge records for more than 60 years (1932–98 at Comstock; 1929–93 at Fennville). The highest average daily flow during the year is in March: 1,379 cfs at Comstock and 2,207 cfs at Fennville. The lowest average daily flow during the year is in August: 576 cfs at Comstock and 949 cfs at Fennville. At Comstock, the median flow is 750 cfs, and flow does not exceed 1,530 cfs more than 10 percent of the time. At Fennville, the median flow is 1,290 cfs, and flow does not exceed 2,450 cfs more than 10 percent of the time (Blumer et al. 1999; BBL 2000b). More recent data (July 2001 to January 2003) from newer gauging stations in Plainwell and Allegan exhibit a similar trend, with the highest flows occurring in March and also in late October (USGS 2003). The flow record shows very little long-term variation because of the rural nature of the watershed and the impoundments along the river. Impoundments tend to buffer the effects of high flow by regulating a river's discharge (BBL 2000b).

At both the Plainwell and Otsego City impoundments, large floodplain areas border the river. The channel upstream of the Plainwell impoundment has large, low-relief floodplain areas on the inside of meander bends and steep banks outside the bends. The banks along the straight channels of the river generally are steep, with some smaller flood-prone areas. Hydraulic modeling (using data from 1984 to 1993) calculated that over the entire area of the Plainwell impoundment, inundation lasted for 6 to 18 days out of the year. The modeled floodplain area was based on the 500-year flood boundary and covers a total of 1,450 acres. The floodplain area 1.5 miles upstream of the former Plainwell dam is the most susceptible to inundation, needing the lowest flow-rate to top its banks. The larger floodplain areas of the Plainwell impoundment (nearest to the dam) have a lesser average hydroperiod of 6 to 8 days, due to the higher flow rate needed for the river to leave the channel (QEA 2001). Based on recent observations, inundation of the floodplain soils in the Plainwell impoundment area has been rare. The reason is that functional dams upstream control the river's flow, and the spillway of the former Plainwell dam allows water to pass over it at a continuous rate, without backing up water. The banks immediately adjacent to the river channel are high enough to accommodate an increased amount of flow, keeping water from flowing onto the floodplain areas. On the rare occasion when the low-relief areas flood, it happens in the early spring. These areas do not stay inundated for more than 7 to 10 days (Hubbell 2003).

Between the Plainwell and Otsego City dams, the river is almost entirely a series of braided channels. The banks adjacent to the river channels are less sheer and stand only slightly above base river elevation. Transitory bars and islands in the river channel also sit only slightly above base river level. Hydraulic modeling determined that these areas were inundated for 5 to 10 days per year. The floodplain area for the model was based on the 500-year flood boundary and is 4,920 acres. Roughly 1 mile downstream of the Plainwell dam, the model shows that the flow rate needed for the river to spill over its banks drops from about 4,500 cfs to 2,500 cfs (QEA 2001). The area is predicted to be the most susceptible to flooding. Recent observations have shown that because of the lack of significant vertical relief in this reach, and the presence of the Otsego City dam, flooding of the floodplain soils is far more common than at the Plainwell impoundment. The duration of inundation has been greater, and can last for weeks at a time, generally in the early spring or fall months. The FEMA Flood Insurance Rate Map of Otsego Township shows that the entire braided channel area lies within the 100-year floodplain (FEMA 1988). The hydroperiod in this reach is more significant, as floodplain soils can remain underwater for weeks at a time during a high flow year (Hubbell 2003).

Aquifers in the Kalamazoo River Valley are almost exclusively made of glacial deposits. Thick sand and gravel beds deposited as the Saginaw and Michigan lobes receded are highly transmissive and produce ample amounts of water for private and municipal use. The sand

and gravel aquifer is unconfined (i.e., not confined under pressure by geologic units above) and bounded below by the Coldwater Shale. The Kalamazoo River, which flows over sand and gravel deposits, is hydraulically coupled with the aquifer. The highly conductive nature of these sand and gravel deposits also aids in mitigating high-flow periods on the river. Most of the rivers and lakes within the Kalamazoo River watershed are gaining, being partially recharged by groundwater from the aquifer (BBL 2000b; KRWPAC 1998).

3.4 Ecology

The Kalamazoo River watershed is part of the Michigan/Indiana Till Plains ecoregion. The ecoregion features a low-relief landscape of glacial plains, hills, valleys, small lakes, and ponds (BBL 2000b). There are seven major native plant communities in the watershed (BBL 2000b, KRWPAC 1998), with transitional zones existing between and within them:

- **Dry Southern Hardwood Forest**—Forests with bur, black, or white oak dominant; found in dry upland areas
- **Mesic Southern Hardwood Forest**—Forests with beech and sugar maple dominant; found in areas with moist soils
- **Wet Lowland Forest**—Forests with willow, cottonwood, silver maple, and ash dominant
- **Sphagnum Bog**—Areas where heathlike shrubs and sphagnum moss are dominant; generally, wet, open, and treeless
- **Grassland-Savanna Complex**—Characterized by a combination of prairies, sedge meadows, and savannas, typically treeless and dominated by grasses or sedges
- **Marsh and Emergent Aquatic Community**—Treeless areas where the water table is above the soil surface most of the growing season
- **Submerged Aquatic Community**—Plant communities that are found in lakes, ponds, and streams, and grow at or below the water's surface

All these communities are found within the Kalamazoo watershed, albeit fragmented because of the agricultural, industrial, and residential development of the region.

The watershed also maintains a number of wetland types, ranging from small riparian wetlands to large hardwood swamps and emergent marshes (BBL 2000b). Wetland features within the area of the Plainwell and Otsego impoundments are described by the USFWS in 1981 (pre-dam removal) as a permanently flooded, lower perennial riverine system with an unconsolidated bottom (BBL 2000b).

The plant communities and wetlands local to this watershed provide excellent habitats for a large number of animal species. Resident and migratory animals are found throughout the watershed. Game species include white-tailed deer, rabbit, fox squirrel, gray squirrel, ring-necked pheasant, ruffed grouse, bobwhite quail, and wild turkey. Furbearing mammals, such as the mink, muskrat, red fox, skunk, opossum, raccoon, weasel, woodchuck, gray fox, badger, and beaver are also found in the region. Migratory waterfowl commonly taking up seasonal residence include the mallard duck, wood duck, red head duck, Canada goose, blue goose, blue-winged teal, and the American coot. The Kalamazoo River between

Plainwell and Otsego can be considered a warm-water fishery dominated by pike, bass, catfish, panfish, carp, and sucker (BBL 2000b; KRWPAC 1998).

The USFWS states that there are two federally endangered species, two federally threatened species, and one federal candidate species that can be present in Allegan County. The Karner blue butterfly and the Indiana bat both are endangered. The bald eagle and Pitcher's thistle (a plant) are both threatened in this region. The eastern massasauga rattlesnake is the lone candidate species (BBL 2000b).

The MDNR lists seven species as endangered or threatened (not including the federally-listed species) in or near the site. Endangered species in this area include the zigzag bladderwort, wild American ginseng, and the log fern (plants), the creek chubsucker (fish), prairie warbler (bird), ottoe skipper (insect), and the spotted turtle (reptile) (BBL 2000b).

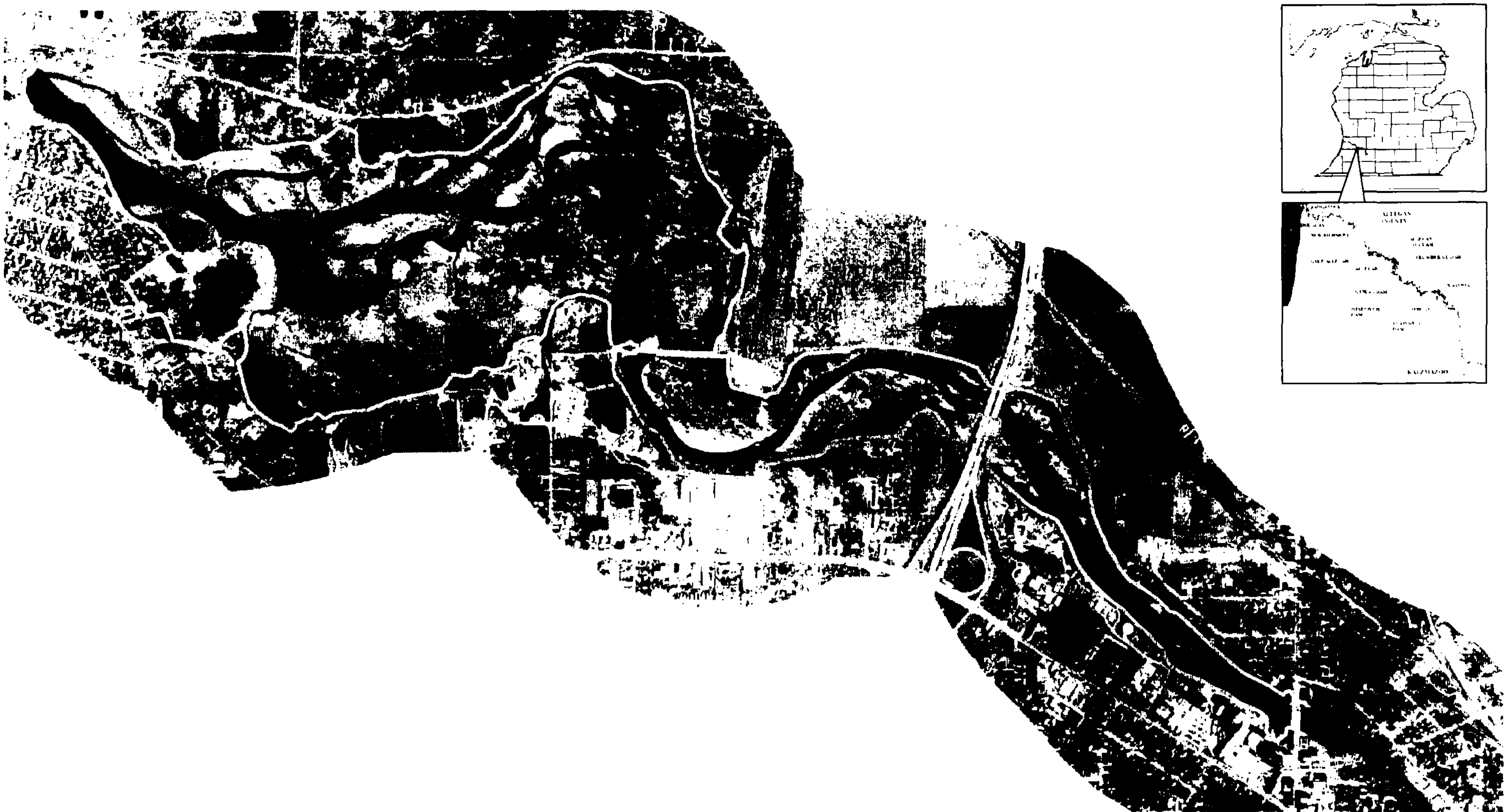
In 2000, BBL requested information from the Nature Conservancy on protected natural areas along the Kalamazoo River. The Nature Conservancy filled that request and concluded that there are no areas of this type near the Plainwell and Otsego sites (BBL 2000b).

3.5 Demographics and Land Use

The Kalamazoo watershed has roughly 400,000 inhabitants, concentrated mostly in the metropolitan areas of Battle Creek and Kalamazoo upstream of the Allegan County impoundments. Following the 2000 U.S. Census, Allegan County had a population of 105,665. The median age is 35.2 years, and 28.9 percent is 18 years old or younger (KRWPAC 1998; Weston 2002; USCB 2003).

The Kalamazoo River flows through two cities and two townships within the site: the cities of Plainwell and Otsego and the townships of Gun Plain and Otsego. The cities of Plainwell and Otsego each have populations of 3,933. The township population of Gun Plain is 5,637, that of Otsego is 4,854 (Weston 2002; USCB 2003).

The 2,020 square miles of the Kalamazoo River watershed are used in several ways, primarily as cropland and pasture (57 percent). Forested land makes up 21 percent, and urban areas and miscellaneous uses account for 17 percent. The remaining 5 percent of the watershed is wetlands and open water (KRWPAC 1998). Land use in the upstream areas of the Plainwell impoundment are primarily urban, consisting of residential, commercial, and industrial uses. Land uses downstream are more rural in nature. The 12th Street Landfill (OU-4) is adjacent to the former Plainwell dam. Near the Otsego City impoundment, land use is primarily rural and residential, with some crop and pasture lands, woodlands, and forests. Because of the braided nature of the river in this area, there are many transient bars and channels (Weston 2002). From the Otsego City Dam to the former Otsego Dam (downstream of the site), there is a higher degree of industrial development as the river passes through Otsego. Further downstream at the Otsego impoundment, the land use is again becomes rural including forest, agriculture, and low-density residential areas (Weston 2002).



Legend

Floodplain Soil Study Area

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Figure 3-1
Floodplain Soil Study Area
Kalamazoo River
Plainwell and Otsego City Impoundments

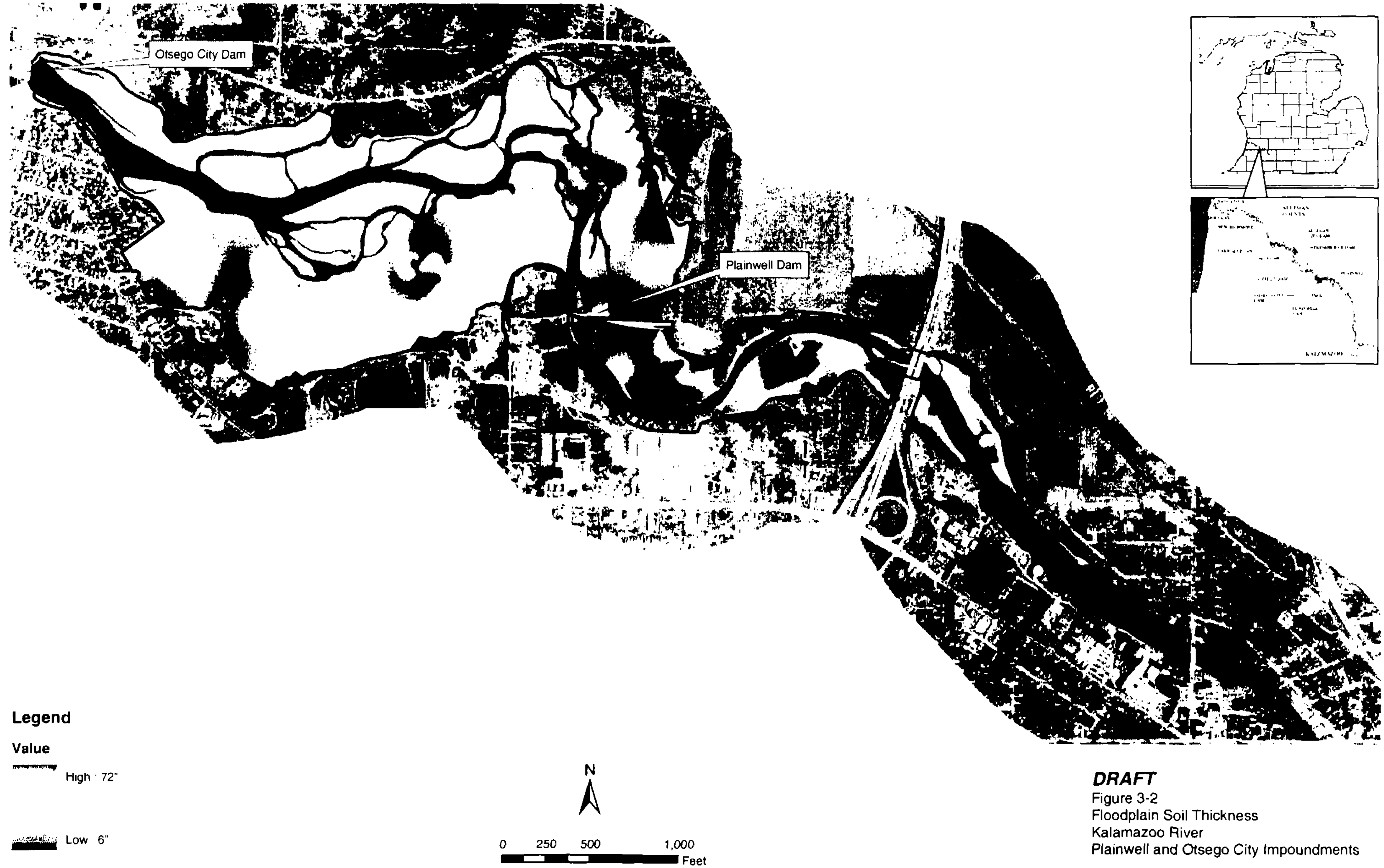

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Figure 3-2
Floodplain Soil Thickness
Kalamazoo River
Plainwell and Otsego City Impoundments

SECTION 4

Nature and Extent of Contamination

This section characterizes the chemical nature of the contaminants of concern in the floodplain soils within the Plainwell and Otsego City impoundments, defines the vertical and horizontal extent of contamination, and quantifies the mass of contaminants and volume of contaminated material. Section 4.1 discusses the nature of the contamination and the environmental media affected. Section 4.2 summarizes the available data and defines the spatial (vertical and horizontal) distribution of the contamination and discusses the relationship of the contamination to the physical characteristics of the floodplain soils. Section 4.3 quantifies the contamination present with estimates of the mass of contaminants and the volume of contaminated environmental media in the impoundments. The discussions in this section will lead into Section 5, which provides an assessment of the fate and transport mechanisms that affect the movement of the contaminants contained in the floodplain soils of the Plainwell and Otsego City impoundments. The results of this analysis will be used in the FS to develop remedial alternatives.

4.1 Summary of Detected Compounds (Nature of Contamination)

Various chemical and physical parameters were analyzed and detected in the floodplain soil samples from the Plainwell and Otsego City impoundments. The detected chemical compounds include PCBs, VOCs, SVOCs, pesticides, dioxins, and metals (including mercury).

4.1.1 PCBs

Based on the National Priorities List site scoring package and the 1991 *Preliminary Public Health Assessment* issued by the U.S. Agency for Toxic Substances and Disease Registry, the primary contaminants of concern in the Kalamazoo River are PCBs. PCBs entered the Kalamazoo River by direct discharge, such as wastewater effluent; indirect discharge through publicly owned treatment works; and upstream nonpoint source runoff (Weston 2002). PCBs were detected in areas of the Kalamazoo River as far upstream as Morrow Lake, throughout the river and associated floodplain, and downstream to its discharge point into Lake Michigan.

4.1.1.1 Data Distribution

The dataset that was used contains floodplain soil data from the 9-year period 1993 to 2001. Most of those data were collected during two major sampling events. In 1993 and 1994, BBL collected floodplain soil samples from the impoundments on behalf of the KRSG for the purposes of an RI, pursuant to an Administrative Order by Consent issued by the MDNR. In 2001, the USEPA conducted a removal assessment at the Kalamazoo River site, between the Otsego City Dam and Main Street in Plainwell.

The final PCB dataset contains more than 1,700 samples collected from the floodplain soils in the Plainwell and Otsego City impoundments. PCB sample results were quantified as total PCB concentrations, calculated by determining the sum of the detected individual PCB

Aroclor results. For samples with all individual PCB Aroclor results quantified as nondetects, one-half the detection limit for the Aroclor methods was used as the PCB result for the purposes of statistical analysis. The adjacent figure shows the frequency of detection above selected concentrations. The discussions in subsequent sections of this report pertain to the total PCB concentration.

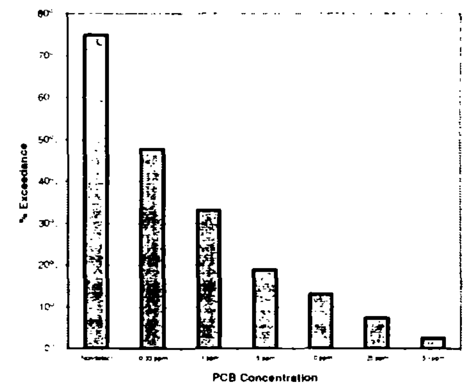


Figure 4-1 plots the relative frequency of all the total PCB concentrations. Figure 4-2 plots PCB concentrations by sampling date and also shows surficial PCB concentration trends. No increasing or decreasing PCB time trends are apparent when comparing PCB data from all depth intervals between 1993/94 and 2000/01. For surficial samples, however, an increase in PCB concentrations between 1993/94 and 2000/01 is apparent, suggesting that a source of PCBs continues to affect the floodplain. Note that this trend may be an artifact of the targeted sampling areas and the objectives of the investigations. See Section 5 for further discussion of trends of PCB concentration.

4.1.1.2 Frequency of Detection

PCBs were detected at levels above the method detection limit in 75 percent (1,284 of 1,709 samples) of the floodplain soil samples collected from the Plainwell and Otsego City impoundment areas. Based on the dataset, PCBs were detected more frequently in samples from the Plainwell impoundment area (90-percent detection frequency) than in samples from the Otsego City impoundment area (50-percent detection frequency). Again, this may be an artifact of the sampling program. For all floodplain soil samples from the Plainwell and Otsego City impoundments, Aroclor-1254 is the predominant PCB detected (quantified in 56 percent of the samples), with Aroclor-1260 (about 50 percent) and Aroclor-1242 (about 42 percent) detected less frequently. Within the Plainwell impoundment area only, Aroclor-1254 and Aroclor-1260 are detected at roughly the same frequency (66 vs. 63 percent). Aroclor-1242 was detected less frequently, in about 46 percent of the samples. For floodplain soil samples collected from the Otsego City impoundment, Aroclor-1254 was the most commonly detected PCB Aroclor (39 percent), Aroclor-1242 the second most frequently detected (35 percent), and Aroclor-1260 least frequently (29 percent).

4.1.2 Other Chemical Constituents Detected

Other chemical constituents detected in samples collected from the floodplain soils of the Plainwell and Otsego City impoundments include VOCs, SVOCs, pesticides, dioxins, and metals (including mercury). Table 4-1 summarizes the detected non-PCB constituents. As stated above, the primary contaminants of concern are PCBs. Further discussion within this report will focus on PCBs only.

TABLE 4-1
Floodplain Soils within Plainwell and Otsego City Impoundments:Summary of Non-PCB Detected Compounds

Parameter	Number of Samples	Number Detected	Percent Detected	Units	Minimum	Maximum	Arithmetic Mean of Detects
Aluminum	4	4	100%	mg/kg	8750	21200	14538
Arsenic	4	4	100%	mg/kg	13	22.5	16.6
Barium	4	4	100%	mg/kg	223	377	298
Beryllium	4	3	75%	mg/kg	ND	0.82	0.77
Cadmium	4	4	100%	mg/kg	3.8	8.3	6.2
Calcium	4	4	100%	mg/kg	18400	36600	27800
Chromium	4	4	100%	mg/kg	100	449	276
Cobalt	4	4	100%	mg/kg	6.8	11.4	8.8
Copper	4	4	100%	mg/kg	128	370	244
Cyanide	4	1	25%	mg/kg	ND	1.5	1.5
Iron	4	4	100%	mg/kg	18900	26400	22025
Lead	4	4	100%	mg/kg	357	520	429
Magnesium	4	4	100%	mg/kg	2980	8810	6933
Manganese	4	4	100%	mg/kg	187	840	485
Mercury	4	4	100%	mg/kg	1.3	2.3	1.8
Nickel	4	4	100%	mg/kg	36	97	70
Potassium	4	2	50%	mg/kg	ND	949	805
Selenium	4	3	75%	mg/kg	ND	2.3	2.1
Silver	4	3	75%	mg/kg	ND	7	4.6
Sodium	4	2	50%	mg/kg	ND	174	158
Thallium	4	1	25%	mg/kg	ND	0.5	0.5
Vanadium	4	4	100%	mg/kg	21.8	29.3	25
Zinc	4	4	100%	mg/kg	330	947	621
Total TCDD	10	9	90%	ng/kg	ND	283	98
Total TCDF	10	10	100%	ng/kg	2	2430	475
Total PECDD	10	2	20%	ng/kg	ND	18	9.5
Total PECDF	10	10	100%	ng/kg	3	2506	428
Total HXCDD	10	9	90%	ng/kg	ND	3834	1378
Total HXCDF	10	9	90%	ng/kg	ND	4668	1125
Total HPCDD	10	10	100%	ng/kg	14	39140	9442
Total HPCDF	10	10	100%	ng/kg	1	7436	2523
OCDD	10	10	100%	ng/kg	478	150400	40923
OCDF	10	10	100%	ng/kg	3	8242	1687
4,4'-DDD	4	3	75%	µg/kg	ND	190	108
Acetone	4	1	25%	µg/kg	ND	49	49
Aldrin	4	4	100%	µg/kg	11	440	166
Alpha Chlordane	4	1	25%	µg/kg	ND	9.8	9.8
Benzo(A)anthracene	4	3	75%	µg/kg	ND	340	240
Benzo(A)pyrene	4	2	50%	µg/kg	ND	230	185
Benzo(B)fluoranthene	4	2	50%	µg/kg	ND	420	320
Benzo(K)fluoranthene	4	1	25%	µg/kg	ND	160	160
Bis(2-ethylhexyl)phthalate	4	1	25%	µg/kg	ND	320	320
Butylbenzylphthalate	4	2	50%	µg/kg	ND	150	123
Chrysene	4	3	75%	µg/kg	ND	420	323
Di-n-butylphthalate	4	3	75%	µg/kg	ND	280	184
Endosulfan I	4	1	25%	µg/kg	ND	6.2	6.2
Endrin Aldehyde	4	1	25%	µg/kg	ND	13	13
Fluoranthene	4	4	100%	µg/kg	220	620	383
Gamma Chlordane	4	3	75%	µg/kg	ND	42	17
Indeno(1,2,3-CD)pyrene	4	1	25%	µg/kg	ND	170	170
Methylene Chloride	4	2	50%	µg/kg	ND	6	5
Phenanthrene	4	3	75%	µg/kg	ND	300	220
Pyrene	4	4	100%	µg/kg	230	550	370
Toluene	4	2	50%	µg/kg	ND	4.0	3.5

TABLE 4-1
Floodplain Soils within Plainwell and Otsego City Impoundments: Summary of non-PCB Detected Compounds

4.1.3 Environmental Media Affected

The floodplain boundaries are well defined by steep banks confining the extensive marshes, and forest surrounds much of the available floodplain (BBL 2000a). Floodplain soils are affected by the transport of sediments containing PCBs to the floodplains during periods of high flow in the adjacent river. During high river flows, instream river sediments are resuspended into the water column and transported onto the floodplain when water levels are high enough to overflow the riverbank. Once on the floodplain, the sediment particles are deposited, become entrained, and become a component of the floodplain soils.

The USGS has explained that lowering of the water levels and demolition of the superstructures of the dams eroded much of the instream lacustrine sediments and subsequent deposition of coarse-grained alluvium in the impounded channel behind the remaining dam foundations (USGS 2002). Drawdown of the three impoundments in the 1980s significantly affected the distribution of PCBs in the river and adjacent floodplain. By lowering water levels in the impoundments, the river was forced to carve a new channel through the impoundment sediment, thereby redistributing thousands of cubic yards of sediment and several tons of PCBs that had been sequestered in the sediment bed of the former impoundments in the downstream reaches of the river (BBL 2000a). Following drawdown, sediments once covered by water were exposed, and they now comprise the largest areas and volumes of soils found in the floodplains of the former impoundments.

4.2 Vertical and Horizontal Extent of PCB Contamination

This section describes the results of the sample analyses used to assess the presence and distribution of PCBs in the floodplain soils in the Plainwell and Otsego City impoundment areas. The analytical data are the result of a number of different investigations conducted by the USEPA, MDEQ, USGS, and the PRPs, as described in Section 2.

4.2.1 Summary of Available PCB Data

Data available from the various studies are included in the final dataset for PCBs provided by the USEPA. Sampling activities that concentrated on the floodplain soils in the Plainwell and Otsego City impoundments resulted in the collection of more than 1,700 individual samples from nearly 300 sampling locations between 1993 and 2001. The samples were analyzed for PCB Aroclors. The individual PCB Aroclors were summed and quantified as total PCBs. Table 4-2 summarizes the number of PCB samples collected. The results of the previous investigations are used to understand the current horizontal and vertical extent of the PCB contamination.

Figure 4-3 indicates the sampling locations within the dataset. Figures 4-4 through 4-9 show the individual sampling locations by depth within the Plainwell impoundment. Figures 4-10 through 4-15 show the individual sampling locations by depth within the Otsego City impoundment.

4.2.2 PCB Results

Average and median PCB concentrations were calculated using the available data and summarized. Table 4-2 is a statistical summary of the total PCB results. Total PCB concentrations range from not detected to 158 ppm, with an average of 5.5 ppm. Total PCB results for individual sampling locations in the Plainwell impoundment are presented in Figures 4-16 through 4-21. Total PCB results for individual sampling locations in the Otsego City impoundment are presented in Figures 4-22 through 4-27.

The existing data indicate that PCB concentrations in the floodplain soils vary by reach. Frequency distributions of PCB concentrations for the Plainwell and Otsego City impoundment areas are shown in Figure 4-28. Figure 4-29 presents a comparison of mean PCB concentrations. It is apparent from Figure 4-29 and Table 4-2 that PCB concentrations in the floodplain soils of the Plainwell impoundment are significantly higher than those of the Otsego City impoundment, with average concentrations of 7.8 and 1.6 ppm, respectively. The median PCB concentrations are 0.70 ppm for the Plainwell impoundment and 0.09 ppm for the Otsego City impoundment. The difference in the observed PCB concentrations in the individual impoundments may be an artifact of the targeted sampling areas or objectives of the investigations in the individual impoundments. A trend of decreasing PCB concentrations with increasing depth below the surface is also seen in Figure 4-29 and Table 4-2. The highest average PCB concentrations typically are detected in the top 12 inches of floodplain soil.

Maximum PCB concentrations at each sampling location are shown in Figures 4-30 and 4-31. In the Plainwell impoundment, 125 of 177 (71 percent) of the sampling locations showed maximum PCB concentrations in the surface layer (0 to 6 inches). Conversely, only 35 percent of sampling locations (42 of 121) in the Otsego City impoundment displayed the maximum PCB concentration in the surface layer.

Cumulative detection frequencies for PCB concentrations in the floodplain soils differ for the two impoundments. Table 4-3 summarizes the breakdown of the cumulative detection frequencies. The floodplain soils from the Plainwell impoundment contain higher levels of PCBs than the floodplain soils from the Otsego City impoundment. For example, 45 percent of the results of sampling from the Plainwell impoundment contain PCB concentrations greater than 1 ppm. Conversely, only 14 percent of the results from the Otsego City impoundment contain PCB levels greater than 1 ppm. The frequency of detection decreases with increasing sample depth, as detailed by the comprehensive summary of the cumulative detection frequencies presented in Table 4-3. Figure 4-32 plots the cumulative detection frequencies for all PCB results.

4.2.3 Spatial Distribution of PCBs

Data interpolation methods were used to estimate the approximate extent of PCB contamination. The methods used a layer-by-layer natural neighbor interpolation technique to generate PCB contour maps. The spatial distribution of the estimated PCB concentrations in the floodplain soils in the impoundment areas are presented in Figures 4-33 through 4-38. The figures illustrate that elevated PCB concentrations typically are confined to the upper 12 to 24 inches of soil. In the Otsego City impoundment, the highest concentrations are encountered near two distinct locations. The highest concentrations are found just upstream of the Otsego City Dam. Additionally, a plume of decreasing PCB concentration with distance is evident within the upper 24 inches, which shows that the 12th Street Landfill was a potential source of PCBs to the floodplain soils. Below 24 inches, little PCB contamination is present in the Otsego City impoundment, as shown in Figures 4-36 through 4-38.

TABLE 4-2
Floodplain Soils within Plainwell and Otsego City Impoundments: Summary of PCB Results

TABLE 4-2
Floodplain Soils within Plainwell and Otsego City Impoundments: Summary of PCB Results

Depth Interval (in.)	Number of Samples	Number Detected	Percent Detected	Units	Minimum	Maximum	Arithmetic Mean	Geometric Mean	Median	Standard Deviation	Lower 95% CL for Mean	Upper 95% CL for Mean
Plainwell and Otsego City Impoundments												
0–6	326	254	78%	ppm	0.003	134.1	11.278	1.270	2.535	18.67	9.254	13.301
6–12	304	245	81%	ppm	0.008	97.4	9.388	0.902	0.935	17.88	7.381	11.395
12–24	386	297	77%	ppm	0.003	84.1	4.295	0.402	0.358	11.99	3.101	5.489
24–36	311	214	69%	ppm	0.004	113.0	2.187	0.206	0.134	8.83	1.208	3.167
36–48	226	161	71%	ppm	0.006	158.0	1.312	0.152	0.125	10.60	-0.066	2.690
>48	156	113	72%	ppm	0.006	96.0	1.084	0.146	0.125	7.71	-0.122	2.290
TOTAL	**1709**	**1284**	**75%**	**ppm**	**0.003**	**158.0**	**5.462**	**0.411**	**0.275**	**14.33**	**4.783**	**6.141**
Plainwell Impoundment												
0–6	200	182	91%	ppm	0.007	134.1	17.046	4.308	7.700	21.42	14.084	20.008
6–12	179	170	95%	ppm	0.008	97.4	14.043	2.965	4.110	20.45	11.056	17.031
12–24	223	207	93%	ppm	0.003	84.1	5.886	0.805	0.661	14.41	3.998	7.773
24–36	191	169	88%	ppm	0.007	113.0	3.161	0.362	0.310	10.86	1.625	4.698
36–48	158	138	87%	ppm	0.006	158.0	1.827	0.211	0.193	12.65	-0.139	3.793
>48	118	101	86%	ppm	0.010	96.0	1.398	0.185	0.158	8.85	-0.193	2.988
TOTAL	**1069**	**967**	**90%**	**ppm**	**0.003**	**158.0**	**7.758**	**0.829**	**0.700**	**16.98**	**6.740**	**8.775**
Otsego City Impoundment												
0–6	126	72	57%	ppm	0.003	58.9	2.121	0.183	0.087	6.16	1.050	3.193
6–12	125	75	60%	ppm	0.008	82.1	2.721	0.164	0.095	10.25	0.931	4.510
12–24	163	90	55%	ppm	0.006	48.8	2.119	0.156	0.095	6.97	1.053	3.185
24–36	120	45	38%	ppm	0.004	28.3	0.637	0.084	0.089	3.29	0.052	1.223
36–48	68	23	34%	ppm	0.008	1.4	0.115	0.071	0.092	0.18	0.073	0.157
>48	38	12	32%	ppm	0.006	0.7	0.112	0.071	0.087	0.13	0.072	0.152
TOTAL	**640**	**317**	**50%**	**ppm**	**0.003**	**82.1**	**1.627**	**0.127**	**0.092**	**6.56**	**1.119**	**2.135**

Note:
USEPA provided dataset was used.
The depth interval for the samples was calculated as the average of the top and bottom sampling depths.

In the Plainwell impoundment, PCB concentrations upstream of the former Plainwell Dam show a relatively uniform concentration gradient throughout the reach. Elevated PCB concentrations (> 5 ppm) are fairly uniform within the surficial layer (0 to 6 inches) of floodplain soils and decrease with depth. The highest PCB concentrations are found in the top 24 inches of floodplain soils (Figures 4-33 through 4-36) and seem highly correlated with the areas containing the highest amounts of fine-grained materials (as shown in Figure 3-2). In particular, a deep pocket of consistently high PCB concentrations (> 25 ppm) with depth (down to 48 inches) is located at the bend of the river upstream of the Plainwell Dam.

Plotting individual PCB concentrations against depth shows that maximum PCB concentrations typically occur within the top 12 inches of floodplain soil. In both impoundments, PCB concentrations tended to be highest in the top 12 inches of floodplain soil sampled and generally decreased with sample depth (Figure 4-39).

4.2.4 Relationship of PCB to Physical Characteristics of the Floodplain Soils

The physical characteristics of the environmental media can sometimes be used to assess the potential for the presence of contamination and to predict the contaminant levels. This section evaluates the relationship between total PCB concentrations and total organic carbon (TOC) and solids content to determine if a positive relationship exists.

4.2.4.1 Total Organic Carbon

More than 1,400 samples were analyzed for TOC and total PCB. The average TOC concentration in the floodplain soils of the Plainwell and Otsego City impoundments was 3.6 percent. Prior investigations concluded that, with the exception of a slight increase of TOC concentrations with increasing PCB concentrations, little correlation was observed between PCB and TOC concentrations (Weston 2002). Figure 4-40 plots the observed relationship between the PCB results and the results of the TOC analyses. Similar to previous investigations, the dataset shows little correlation ($r = 0.069$) between PCBs and TOC and a very low correlation coefficient ($r^2 = 0.005$).

4.2.4.2 Total Solids

Total solids results for floodplain soil samples collected from the Plainwell and Otsego City impoundment areas ranged from 8.6 to 100 percent, averaging 58 percent. Figure 4-41 plots the observed relationship between PCB concentrations and solids content. No significant correlation was observed. The data show a slight trend of decreasing PCB concentrations with increasing solids content ($r = -0.13$). Again, the correlation coefficient was very low ($r^2 = 0.02$).

4.3 Mass and Volume of PCB-Contaminated Material

During the 2001 removal assessment, the USEPA estimated that the floodplain soils in the Plainwell impoundment contain more than 340,000 cubic yards of PCB-contaminated material with 5,457 pounds of PCBs (USEPA 2002). No specific computations of mass and volume of PCB contamination in floodplain soils were made for the Otsego City impoundment. The volume of PCB-contaminated floodplain soil and the associated mass of PCBs were revised using the PCB results in the final dataset and the available physical data. The estimation methods and revised estimates of mass and volume are discussed below.

TABLE 4-3
Floodplain Soils within Plainwell and Otsego City Impoundments: Cumulative Detection Frequencies by Depth

TABLE 4-3
Floodplain Soils within Plainwell and Otsego City Impoundments: Cumulative Detection Frequencies by Depth

Depth Interval (in.)	Number of Samples	Number Detected	% Detected	Number > 0.33 ppm	% > 0.33 ppm	Number > 1 ppm	% > 1 ppm	Number > 5 ppm	% > 5 ppm	Number > 10 ppm	% > 10 ppm	Number > 25 ppm	% > 25 ppm	Number > 50 ppm	% > 50 ppm
Plainwell and Otsego City Impoundments															
0–6	326	254	78%	219	67%	199	61%	139	43%	92	28%	54	17%	16	5%
6–12	304	245	81%	188	62%	149	49%	96	32%	72	24%	42	14%	16	5%
12–24	386	297	77%	198	51%	120	31%	56	15%	44	11%	18	5%	9	2%
24–36	311	214	69%	109	35%	59	19%	24	8%	14	5%	10	3%	1	0%
36–48	226	161	71%	63	28%	29	13%	7	3%	3	1%	1	0%	1	0%
>48	156	113	72%	40	26%	19	12%	3	2%	1	1%	1	1%	1	1%
TOTAL	**1709**	**1284**	**75%**	**817**	**48%**	**575**	**34%**	**325**	**19%**	**226**	**13%**	**126**	**7%**	**44**	**3%**
Plainwell Impoundment															
0–6	200	182	91%	169	85%	160	80%	122	61%	89	45%	53	27%	15	8%
6–12	179	170	95%	148	83%	128	72%	83	46%	63	35%	38	21%	14	8%
12–24	223	207	93%	153	69%	95	43%	43	19%	32	14%	13	6%	9	4%
24–36	191	169	88%	93	49%	54	28%	21	11%	12	6%	9	5%	1	1%
36–48	158	138	87%	61	39%	28	18%	7	4%	3	2%	1	1%	1	1%
>48	118	101	86%	38	32%	19	16%	3	3%	1	1%	1	1%	1	1%
TOTAL	**1069**	**967**	**90%**	**662**	**62%**	**484**	**45%**	**279**	**26%**	**200**	**19%**	**115**	**11%**	**41**	**4%**
Otsego City Impoundment															
0–6	126	72	57%	50	40%	39	31%	17	13%	3	2%	1	1%	1	1%
6–12	125	75	60%	40	32%	21	17%	13	10%	9	7%	4	3%	2	2%
12–24	163	90	55%	45	28%	25	15%	13	8%	12	7%	5	3%	0	0%
24–36	120	45	38%	16	13%	5	4%	3	3%	2	2%	1	1%	0	0%
36–48	68	23	34%	2	3%	1	1%	0	0%	0	0%	0	0%	0	0%
>48	38	12	32%	2	5%	0	0%	0	0%	0	0%	0	0%	0	0%
TOTAL	**640**	**317**	**50%**	**155**	**24%**	**91**	**14%**	**46**	**7%**	**26**	**4%**	**11**	**2%**	**3**	**0%**

Note:
USEPA provided dataset was used.

4.3.1 Estimation Methods

Mass and volume estimates were calculated for individual depth intervals in the floodplain soil areas. Grids were prepared using available field data showing the soil thickness and concentration of PCBs in the floodplain soils of the Plainwell and Otsego City impoundments. PCB data and soil thickness information was extrapolated between actual data points to prepare the soil grids for the impoundments. The interpolation method used was the natural neighbor method. The interpolations of soil thickness and PCB concentration also were used to generate the PCB contour maps (Figures 4-33 through 4-38).

The arithmetic average PCB concentration for each depth interval (layer) was also calculated. (Note: Duplicate values were averaged, and one-half of the detection limit was used for nondetects when encountered.) An empirical bulk density value (2,000 lb/yd^3) was used to calculate the PCB mass estimates. Using soil thickness and surface area data, the volume of PCB-contaminated materials was calculated.

4.3.2 Estimates of PCB Mass and Volume of PCB-Contaminated Materials

Using the PCB results and GIS interpolation techniques, the total PCB mass and volume of PCB-contaminated material were calculated. For purposes of a removal assessment, mass and volume estimates were calculated for defined layers of floodplain soil (0 to 6, 6 to 12, 12 to 24, 24 to 36, 36 to 48, and 48 to 60 inches) (Table 4-4). The PCB mass and volume estimates were also calculated using several different PCB concentration thresholds (Table 4-5). The results of the calculations by depth interval are illustrated in Figure 4-42. Similar to the observations made previously, it is apparent that most of the PCB mass is contained within the top 12 to 24 inches of floodplain soils in the two impoundments.

Table 4-4 shows that the total PCB mass contained in the Otsego City impoundment (6,656 pounds) is greater than that in the Plainwell impoundment (5,097 pounds). However, the PCB mass is contained in a soil volume more than four times as large as within the Plainwell impoundment (1.3 million cubic yards compared to 0.3 million cubic yards). PCB mass to soil volume ratios were calculated by dividing the PCB mass by the soil volume (Table 4-6). These ratios were calculated to evaluate which areas contain the highest PCB mass by volume. The lower PCB mass-to-volume ratios for the Otsego City impoundment (0.005) compared to the Plainwell impoundment (mass-to-volume ratio of 0.015) are a function of the much larger surface area and floodplain soil volume, and also the lower average PCB concentration, in the impoundment.

4.3.3 Comparison to Historical Estimates and Other Estimates

Other interested parties have calculated independent estimates of the mass of PCBs and volume of contaminated material in the floodplain soils of the Plainwell and Otsego City impoundment areas. Those estimates are summarized in Table 4-7 for comparison. Note that these estimates employed different methodologies to calculate the mass of PCBs and volume of floodplain contaminated sediments. The methods employed are presented in Appendix A.

TABLE 4-4
Floodplain Soils within Plainwell and Otsego City Impoundments: Mass and Volume Estimates by Depth

Depth Interval (in.)	Plainwell Impoundment	Otsego City Impoundment	Plainwell and Otsego City Impoundments
PCB Mass (lb)			
0–6	1,456	1,815	3,271
6–12	1,406	2,540	3,946
12–24	1,185	2,170	3,355
24–36	417	123	540
36–48	173	8	181
48-60	460	NA	460
Total	**5,097**	**6,656**	**11,753**
PCB-Contaminated Volume (cubic yards)			
0–6	52,165	237,119	289,283
6–12	50,685	236,993	287,677
12–24	93,695	461,440	555,135
24–36	76,216	326,159	402,375
36–48	48,952	72,929	121,881
48–60	22,387	NA	22,387
Total	**344,098**	**1,334,640**	**1,678,739**

Note:
USEPA provided dataset was used.

TABLE 4-5
Floodplain Soils within Plainwell and Otsego City Impoundments:
Mass and Volume Estimates Above Selected PCB Levels

PCB Level	Plainwell Impoundment	Otsego City Impoundment	Plainwell and Otsego City Impoundments
PCB Mass (lb)			
≥ 0.33 ppm	5,083	6,480	11,563
≥ 1 ppm	4,987	6,290	11,277
≥ 2 ppm	4,831	6,024	10,855
≥ 5 ppm	4,472	5,377	9,849
≥ 10 ppm	3,954	4,266	8,220
≥ 25 ppm	2,256	2,545	4,801
Total	**5,097**	**6,656**	**11,753**
Volume of PCB-Contaminated Volume (yd^3)			
≥ 0.33 ppm	300,746	513,344	814,090
≥ 1 ppm	225,127	355,433	580,560
≥ 2 ppm	171,066	263,196	434,262
≥ 5 ppm	114,952	162,733	277,685
≥ 10 ppm	79,426	86,170	165,596
≥ 25 ppm	27,242	29,576	56,818
Total	**344,098**	**1,334,640**	**1,678,738**

Note:
USEPA provided dataset was used.

TABLE 4-6
PCB Mass:Volume Ratios

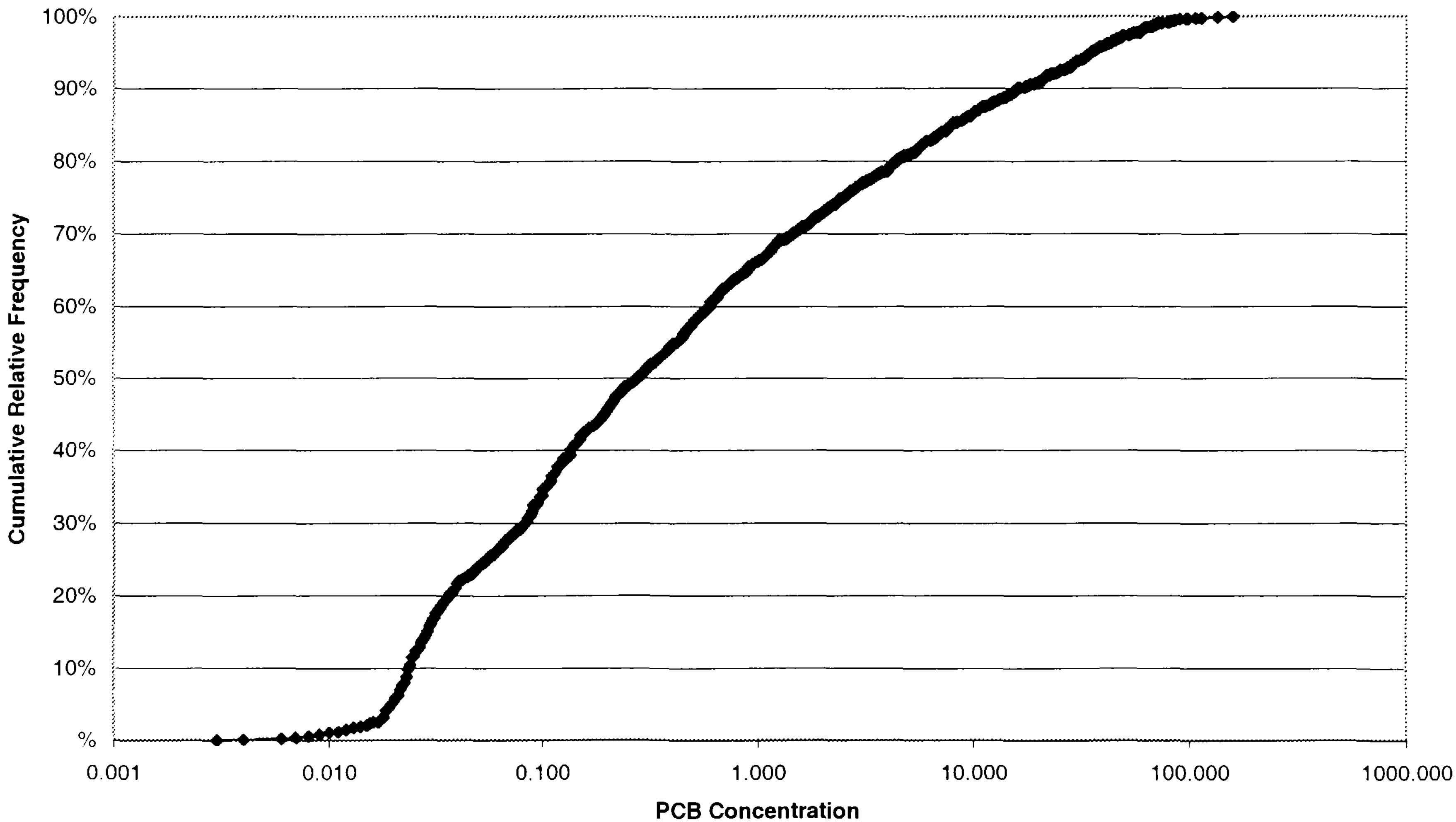
Depth Interval (in.)	Plainwell Impoundment	Otsego City Impoundment	Plainwell and Otsego City Impoundments
0–6	0.028	0.008	0.011
6–12	0.028	0.011	0.014
12–24	0.013	0.005	0.006
24–36	0.005	0.0004	0.001
36–48	0.004	0.0001	0.001
48–60	0.021	NA	0.021
Total	**0.015**	**0.005**	**0.007**

TABLE 4-7
Floodplain Soils within Plainwell and Otsego City Impoundments Comparison of Mass and Volume Estimates Above Selected PCB Levels

	RI Estimates	MDEQ (Kern) Estimates*	KRSG (LTI) Estimates
PCB Mass (lb)			
Plainwell Impoundment			
≥ 0.33 ppm	5,083	NA	2,681
≥ 1 ppm	4,987	NA	2,558
≥ 2 ppm	4,831	NA	2,406
≥ 5 ppm	4,472	NA	2,079
≥ 10 ppm	3,954	NA	1,687
≥ 25 ppm	2,256	NA	961
Otsego City Impoundment			
≥ 0.33 ppm	6,480	NA	1,327
≥ 1 ppm	6,290	NA	1,159
≥ 2 ppm	6,024	NA	997
≥ 5 ppm	5,377	NA	630
≥ 10 ppm	4,266	NA	289
≥ 25 ppm	2,545	NA	60
Volume of PCB-Contaminated Volume (cubic yards)			
Plainwell Impoundment			
≥ 0.33 ppm	300,746	247,000	267,237
≥ 1 ppm	225,127	247,000	168,555
≥ 2 ppm	171,066	245,000	114,128
≥ 5 ppm	114,952	225,000	62,842
≥ 10 ppm	79,426	170,000	35,549
≥ 25 ppm	27,242	37,000	12,180
Otsego City Impoundment			
≥ 0.33 ppm	513,344	409,000	293,375
≥ 1 ppm	355,433	354,000	148,318
≥ 2 ppm	263,196	275,000	91,002
≥ 5 ppm	162,733	146,000	33,476
≥ 10 ppm	86,170	39,000	9,265
≥ 25 ppm	29,576	17,000	876

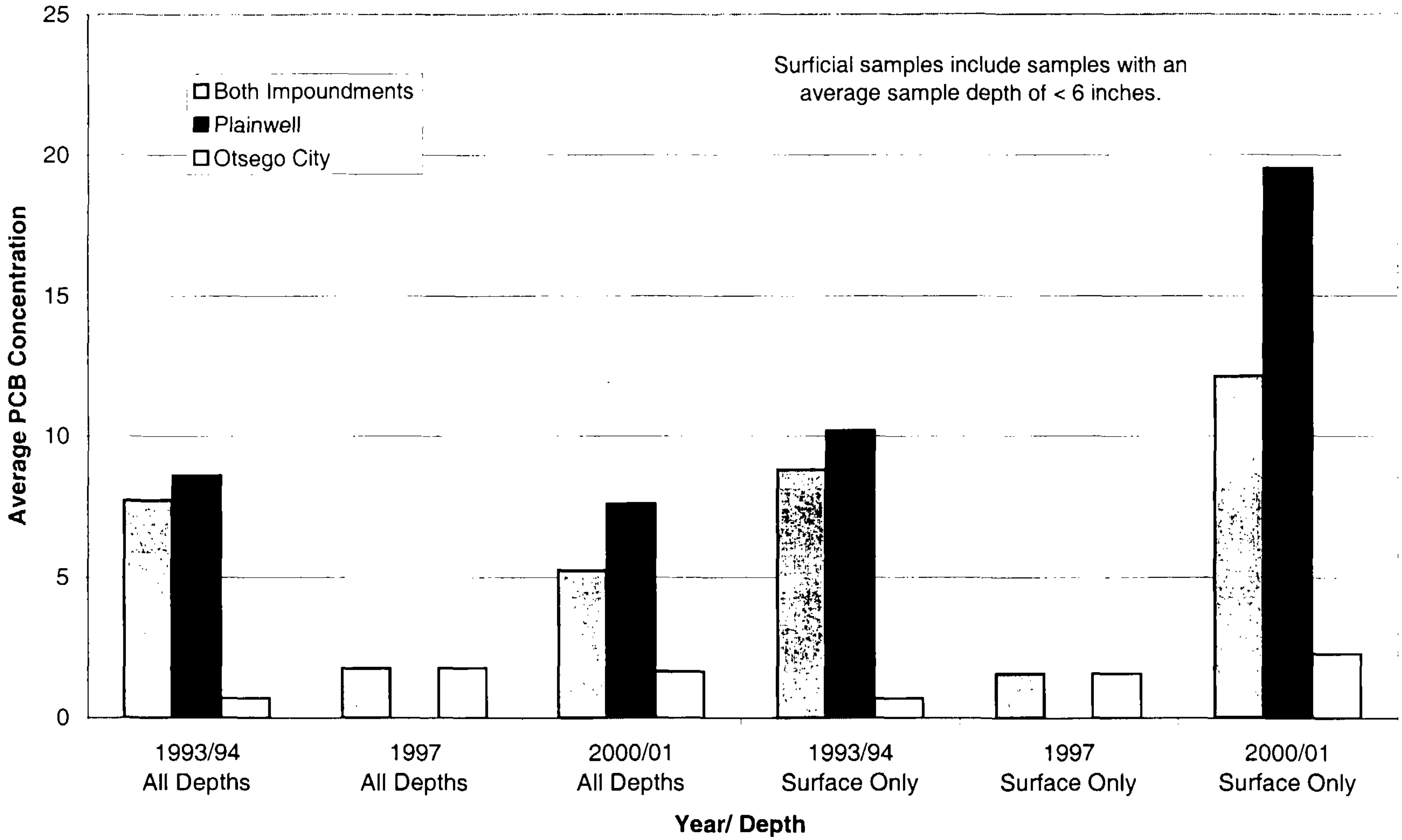
*Average volume estimates by Kern used.

Figure 4-1
Kalamazoo River RI
Floodplain Soils - Plainwell and Otsego City Impoundments
Cumulative Frequency Distribution of PCB Concentrations



MKE\042150001

Figure 4-2
Kalamazoo River RI
Floodplain Soils - Plainwell and Otsego City Impoundments
Average PCB Concentration by Year Sampled



MKE\042150001

Legend

Otsego City Sample Location

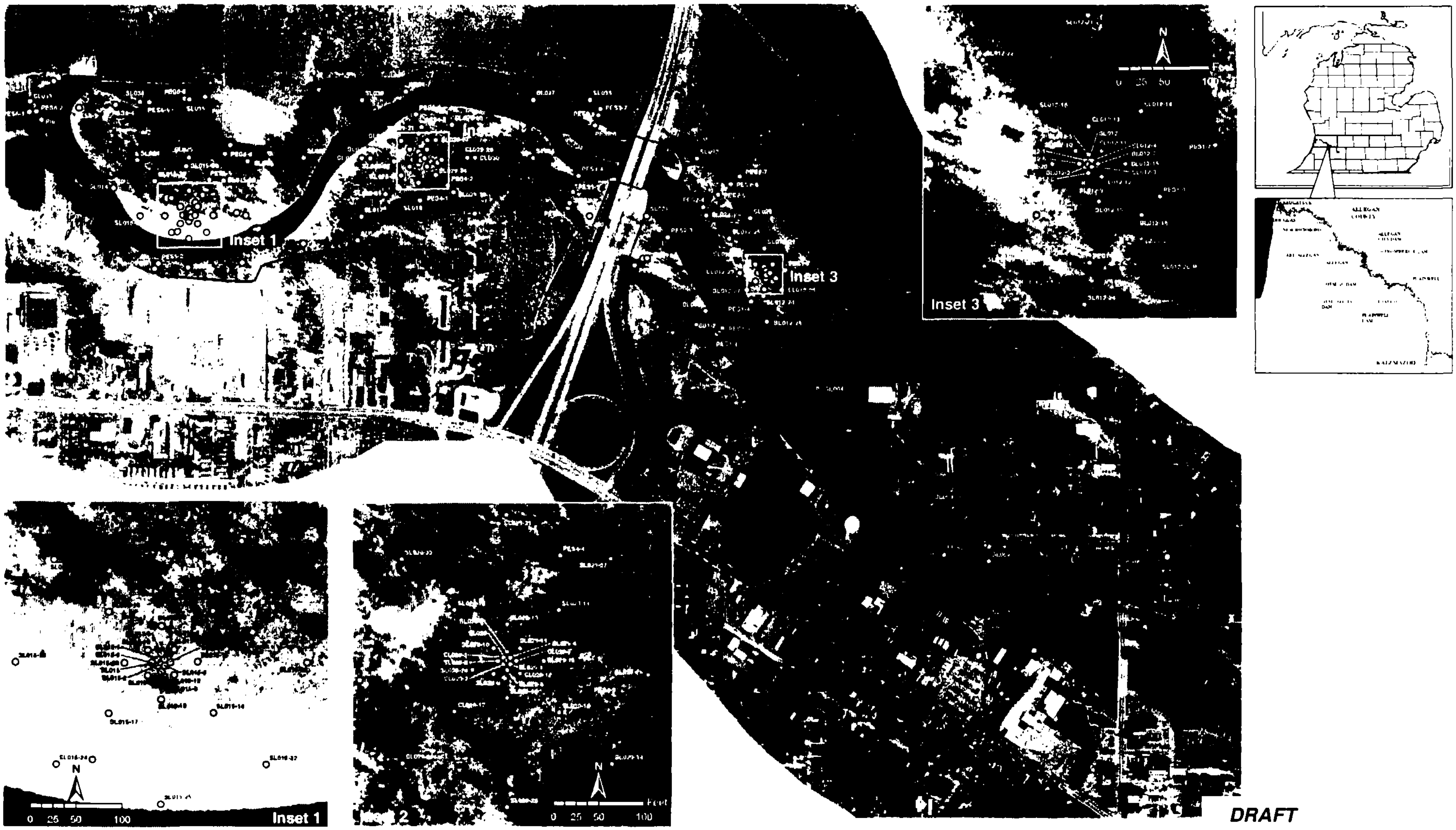
Plainwell Sample Location

N

0 250 500 1,000 Feet

DRAFT

Figure 4-3
Kalamazoo River RI
Plainwell and Otsego City Impoundments
Sample Locations - All Depths



Legend

N

Feet

0 300 600 1,200

DRAFT

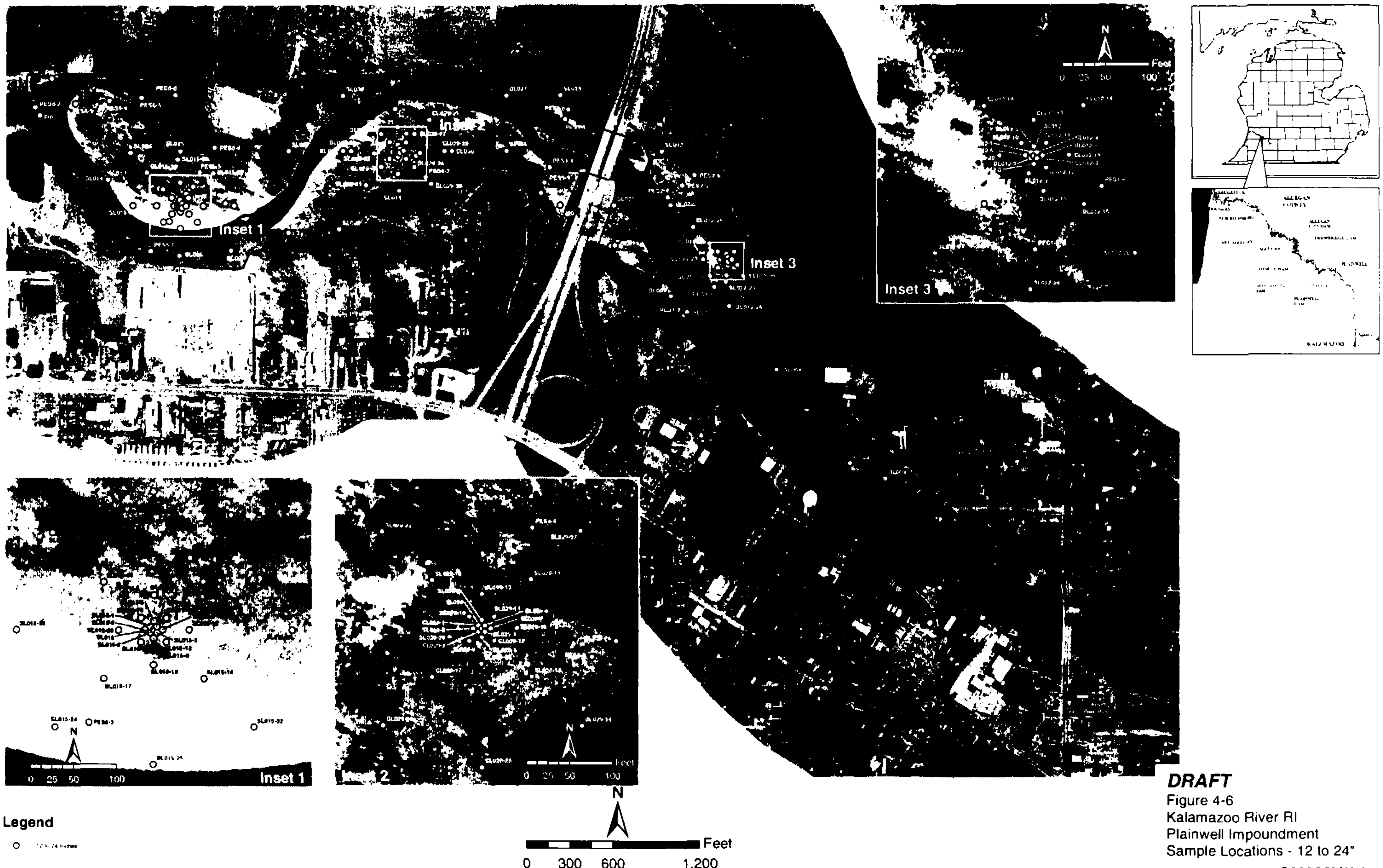
Figure 4-4
Kalamazoo River RI
Plainwell Impoundment
Sample Locations - 0 to 6"

CH2MHILL

DRAFT

Figure 4-5
Kalamazoo River RI
Plainwell Impoundment
Sample Locations - 6 to 12"

CH2MHILL



DRAFT
Figure 4-6
Kalamazoo River RI
Plainwell Impoundment
Sample Locations - 12 to 24"

CH2MHILL

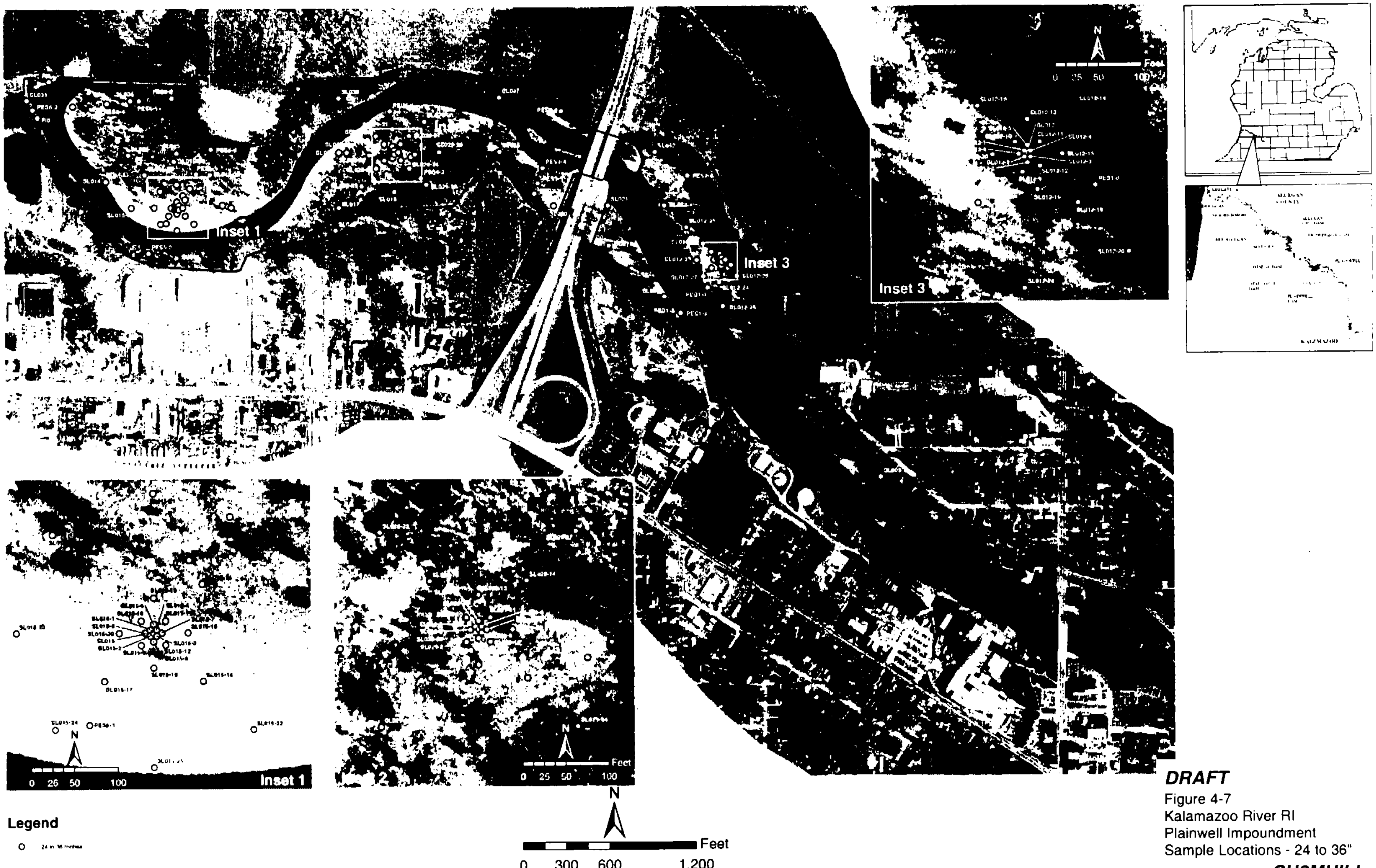


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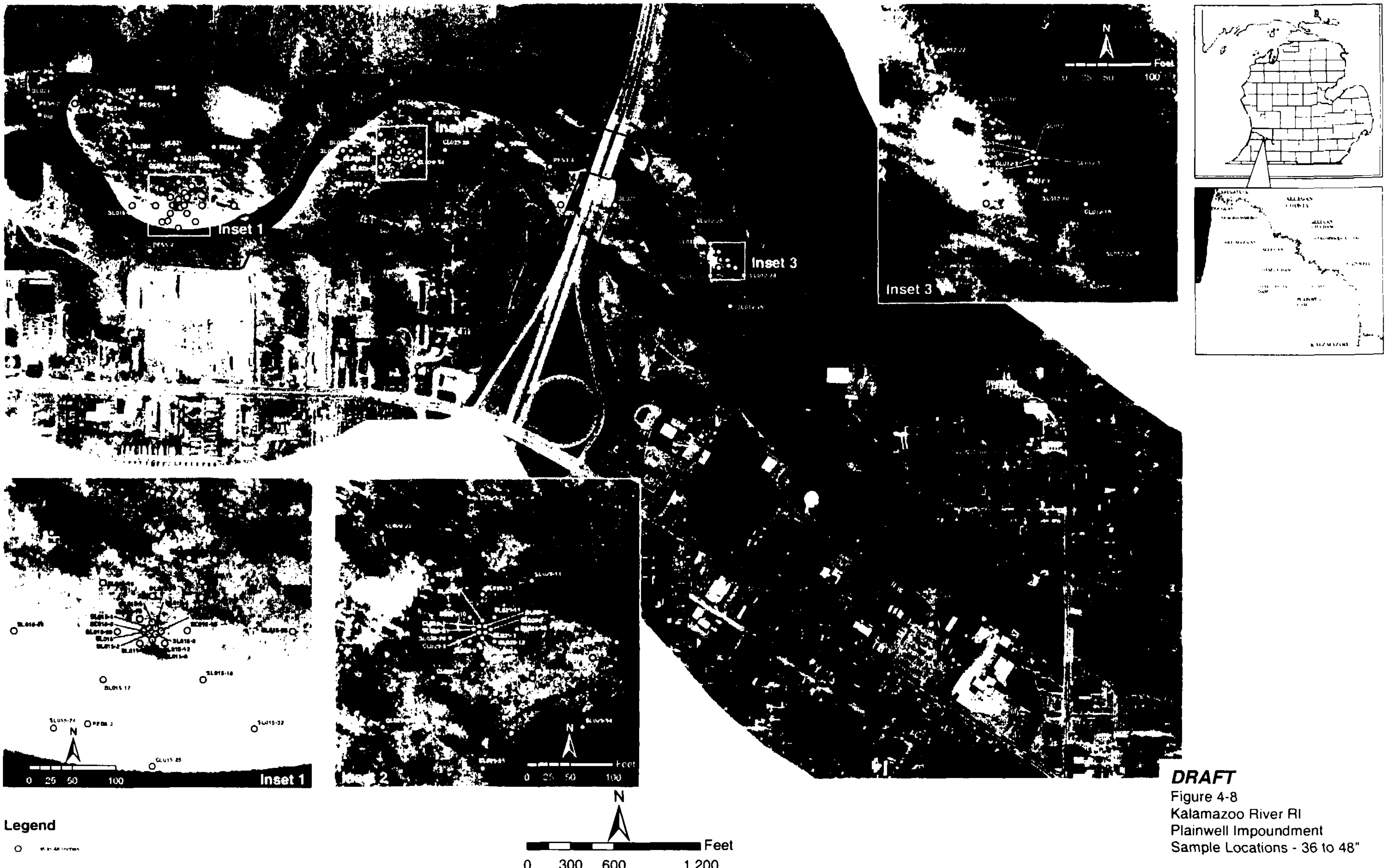
Figure 4-7
Kalamazoo River RI
Plainwell Impoundment
Sample Locations - 24 to 36"

CH2MHILL



DRAFT
Figure 4-8
Kalamazoo River RI
Plainwell Impoundment
Sample Locations - 36 to 48"

DRAFT
Figure 4-9
Kalamazoo River RI
Plainwell Impoundment
Sample Locations - Over 48"

CH2MHILL

Legend

○ Surface to 6 Inches

N

Feet

0 300 600 1,200

DRAFT

Figure 4-10
Kalamazoo River RI
Otsego City Impoundment
Sample Locations - 0 to 6"

CH2MHILL

Legend

○ 6 to 12 Inches

N

Feet
0 300 600 1,200

DRAFT
Figure 4-11
Kalamazoo River RI
Otsego City Impoundment
Sample Locations - 6 to 12"

CH2MHILL

Legend

o 12 to 24 Inches

N

0 300 600 1,200 Feet

DRAFT

Figure 4-12
Kalamazoo River RI
Otsego City Impoundment
Sample Locations - 12 to 24"

CH2MHILL

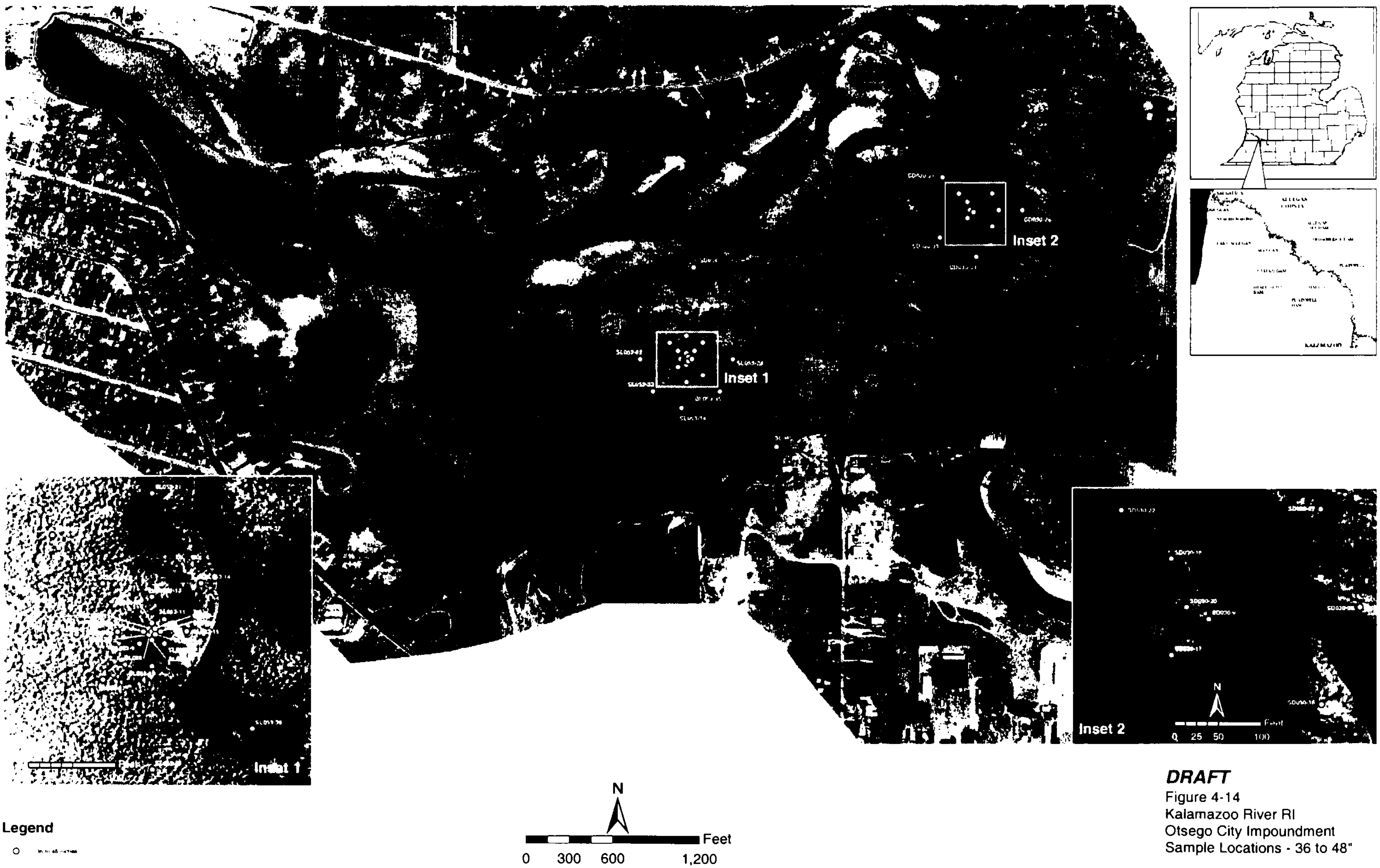
Legend

24 to 36 Inches

N
Feet
0 300 600 1,200

DRAFT
Figure 4-13
Kalamazoo River RI
Otsego City Impoundment
Sample Locations - 24 to 36"

CH2MHILL



Legend

DRAFT

Figure 4-14
Kalamazoo River RI
Otsego City Impoundment
Sample Locations - 36 to 48"

CH2MHILL

Legend

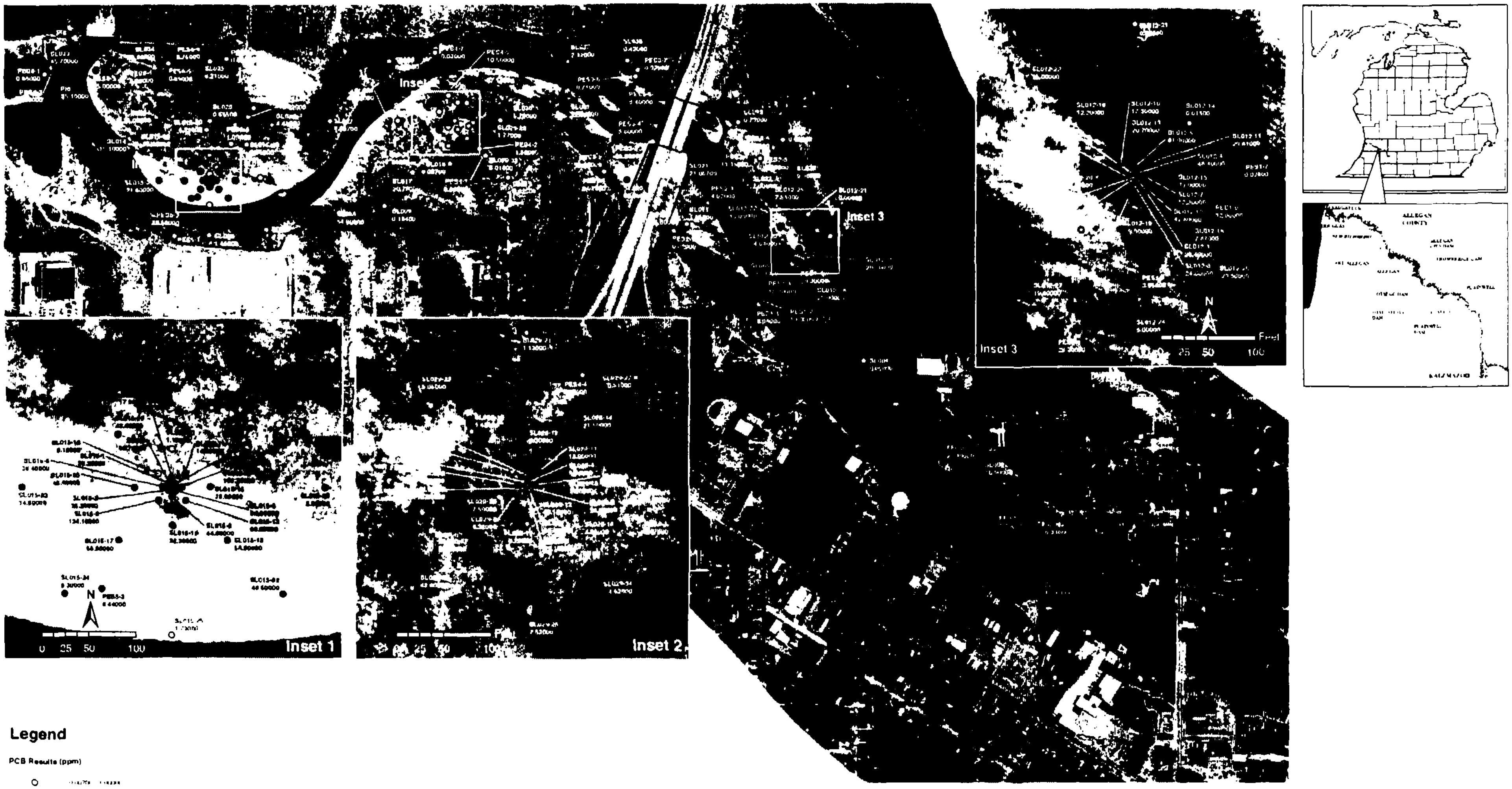
N

Feet

0 300 600 1,200

DRAFT

Figure 4-15
Kalamazoo River RI
Otsego City Impoundment
Sample Locations - Over 48"



Legend

PCB Results (ppm)

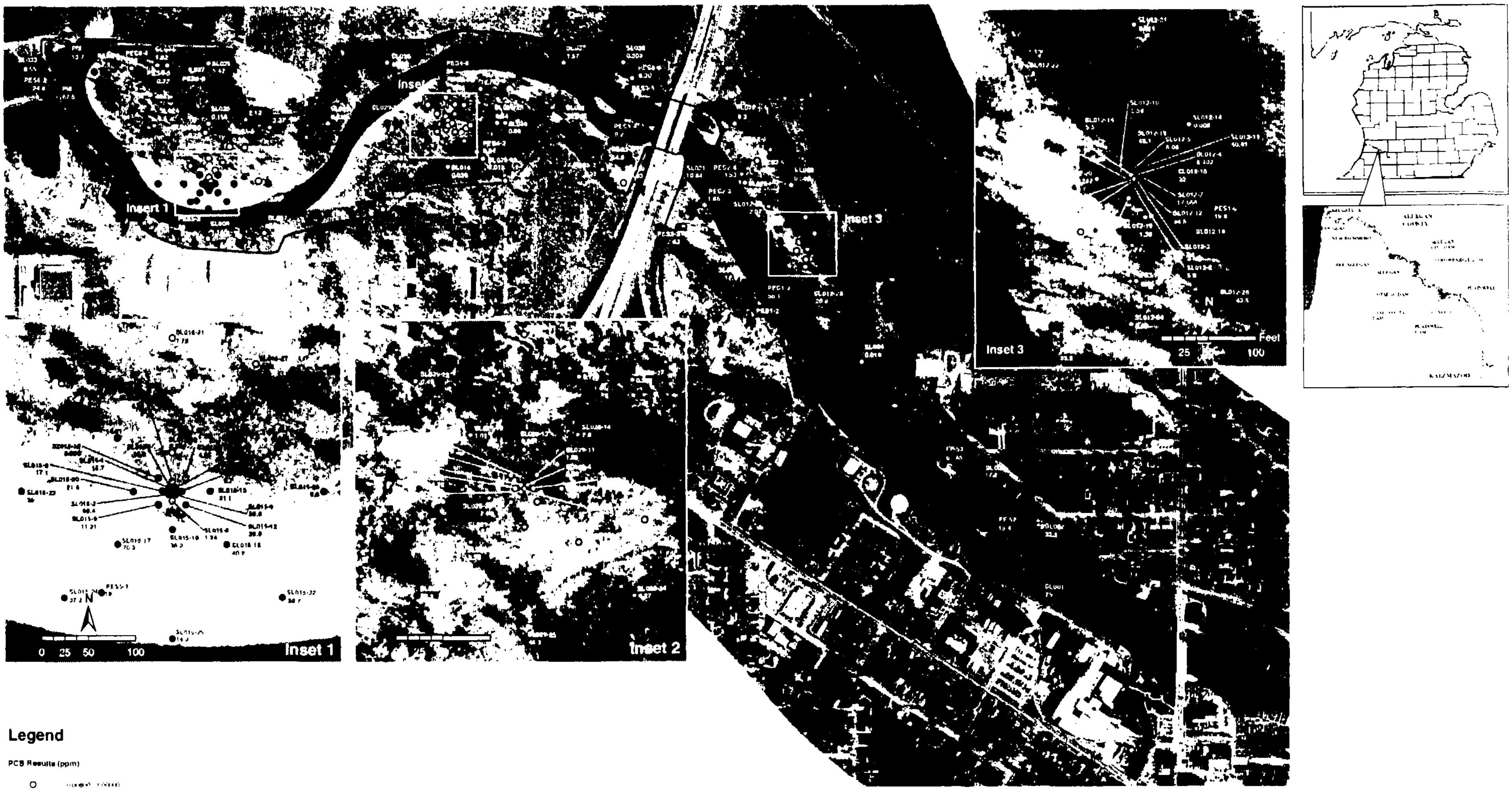
N

Feet

0 300 600 1,200

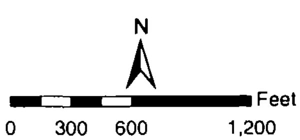
DRAFT

Figure 4-16
Kalamazoo River RI
Plainwell Impoundment
Sample Locations - 0 to 6"
PCB Results



Legend

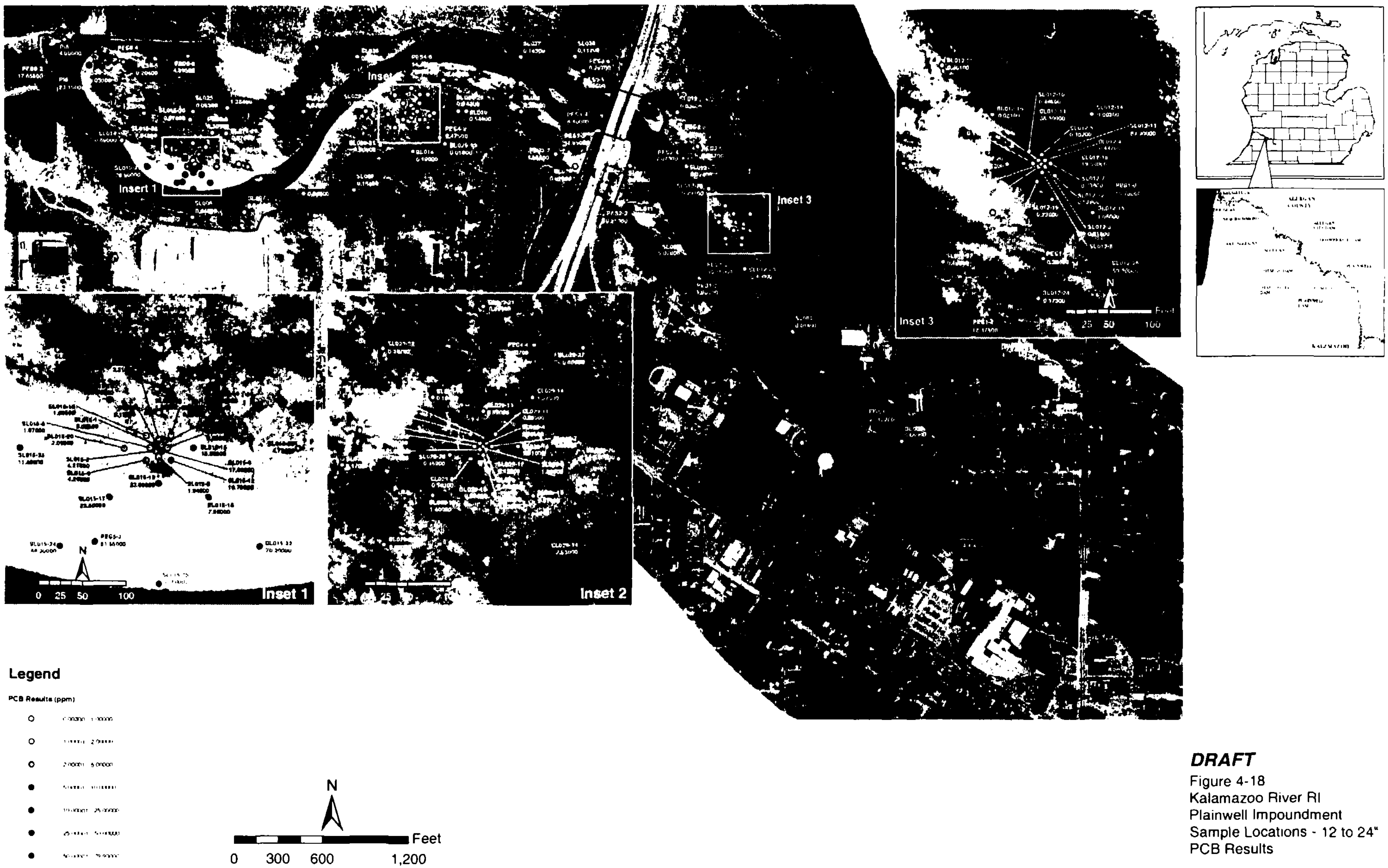
PCB Results (ppm)



DRAFT

Figure 4-17
Kalamazoo River RI
Plainwell Impoundment
Sample Locations - 6 to 12"
PCB Results

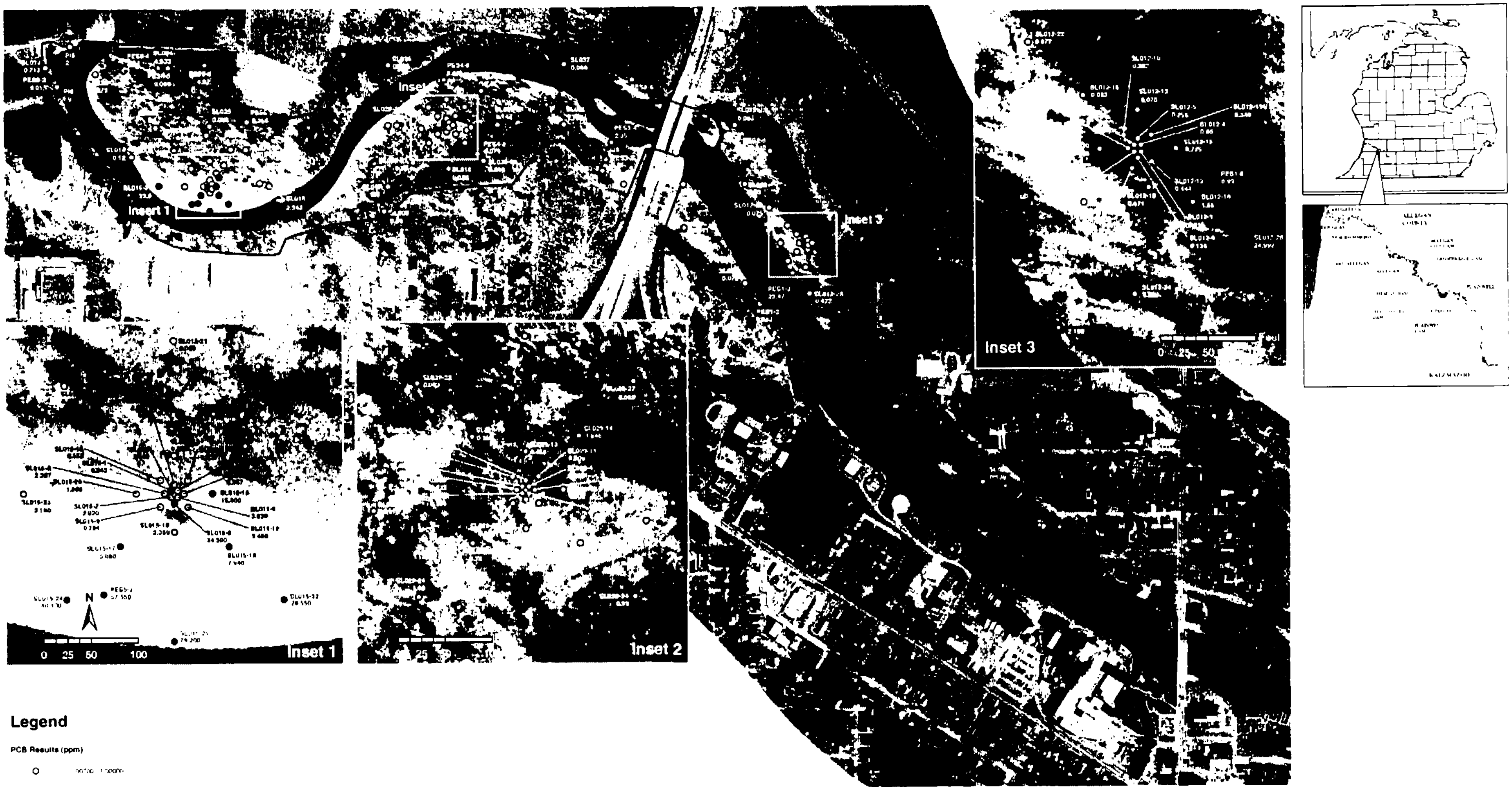
CH2MHILL



DRAFT

Figure 4-18
Kalamazoo River RI
Plainwell Impoundment
Sample Locations - 12 to 24"
PCB Results

CH2MHILL



Legend

PCB Results (ppm)

N

0 300 600 1,200 Feet

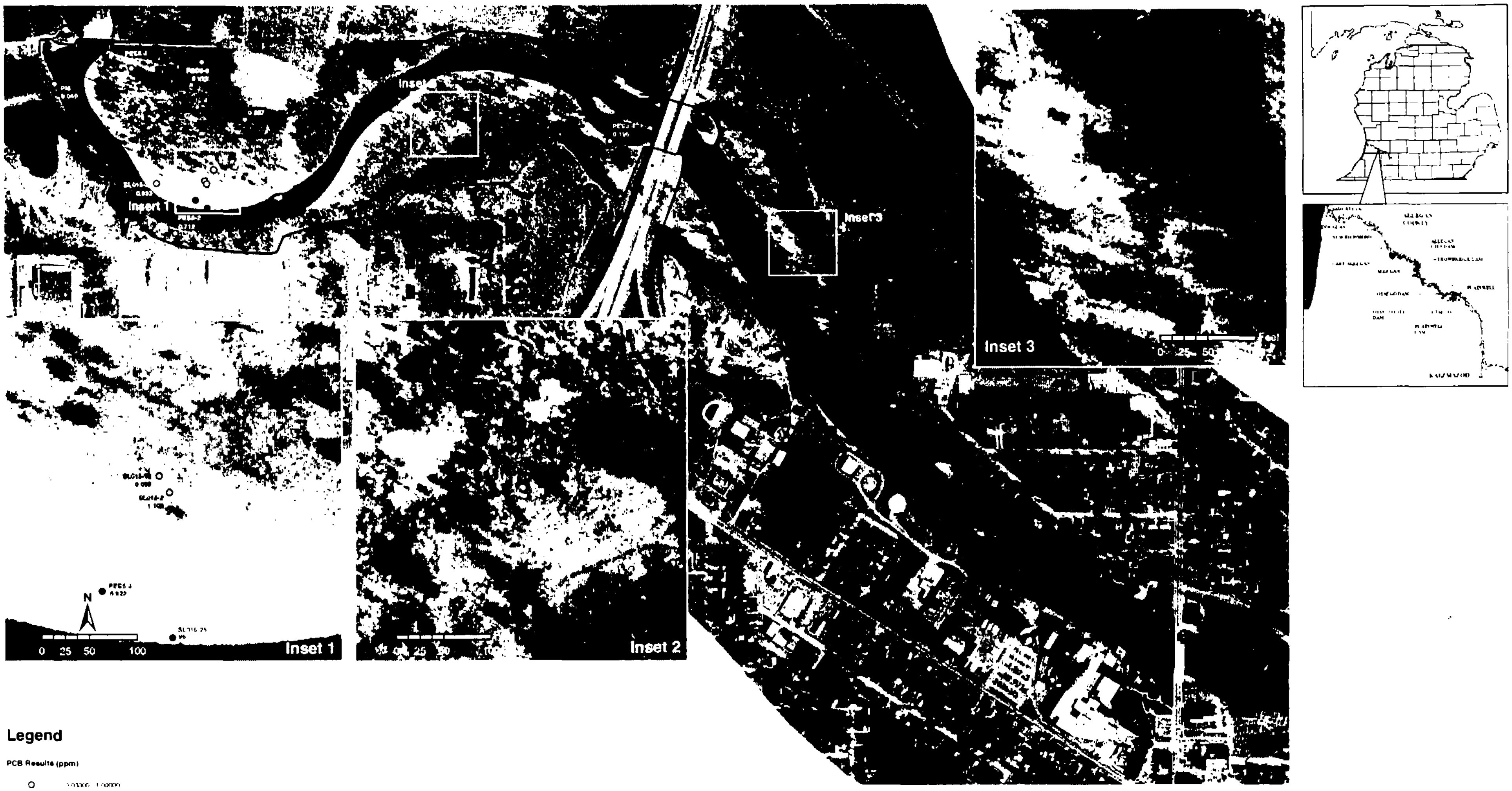
DRAFT

Figure 4-19
Kalamazoo River RI
Plainwell Impoundment
Sample Locations - 24 to 36"
PCB Results

CH2MHILL

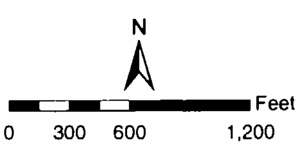
DRAFT

Figure 4-20
Kalamazoo River RI
Plainwell Impoundment
Sample Locations - 36 to 48"
PCB Results



Legend

PCB Results (ppm)



DRAFT

Figure 4-21
Kalamazoo River RI
Plainwell Impoundment
Sample Locations - Over 48"
PCB Results

CH2MHILL

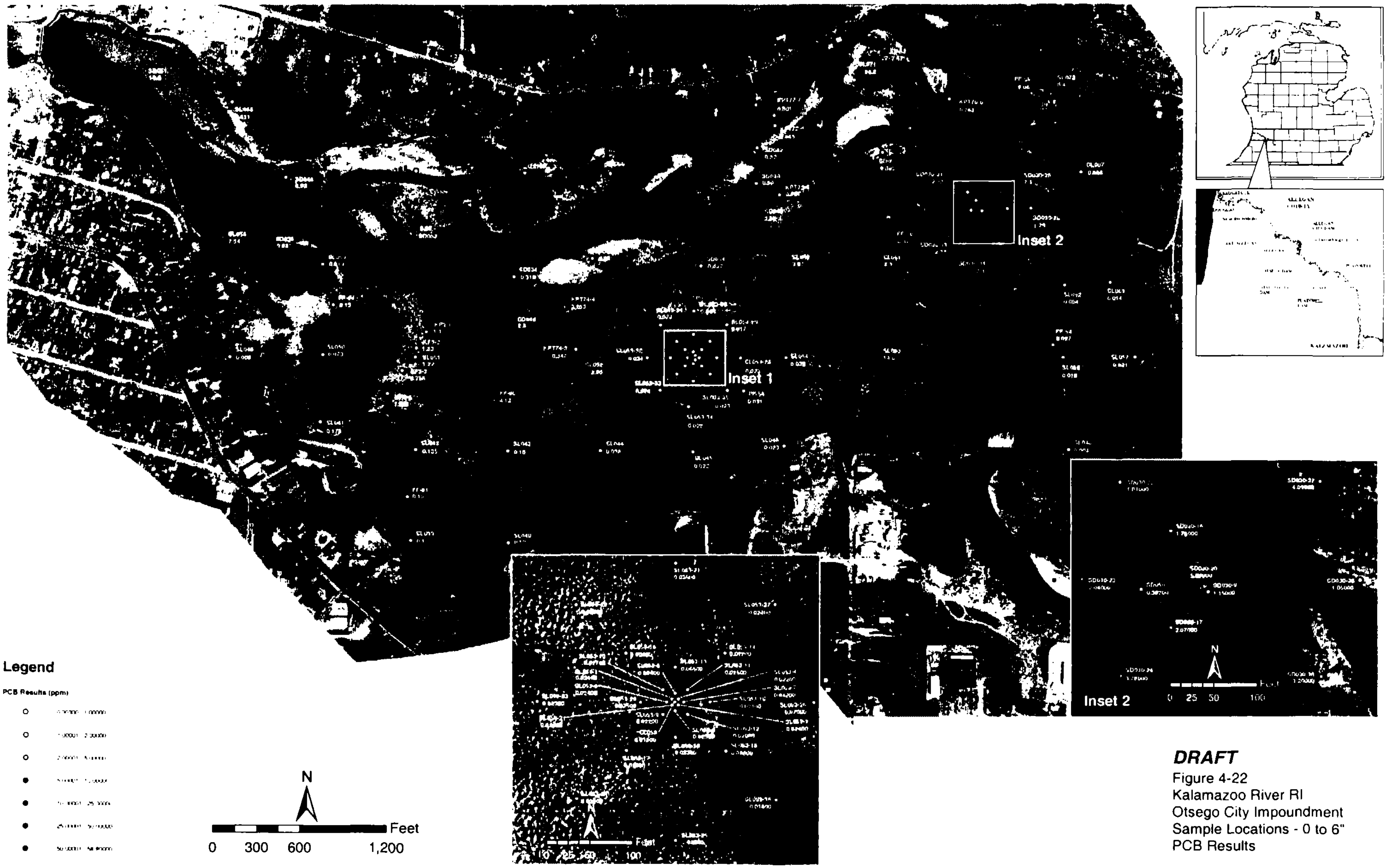


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Figure 4-22
Kalamazoo River RI
Otsego City Impoundment
Sample Locations - 0 to 6"
PCB Results

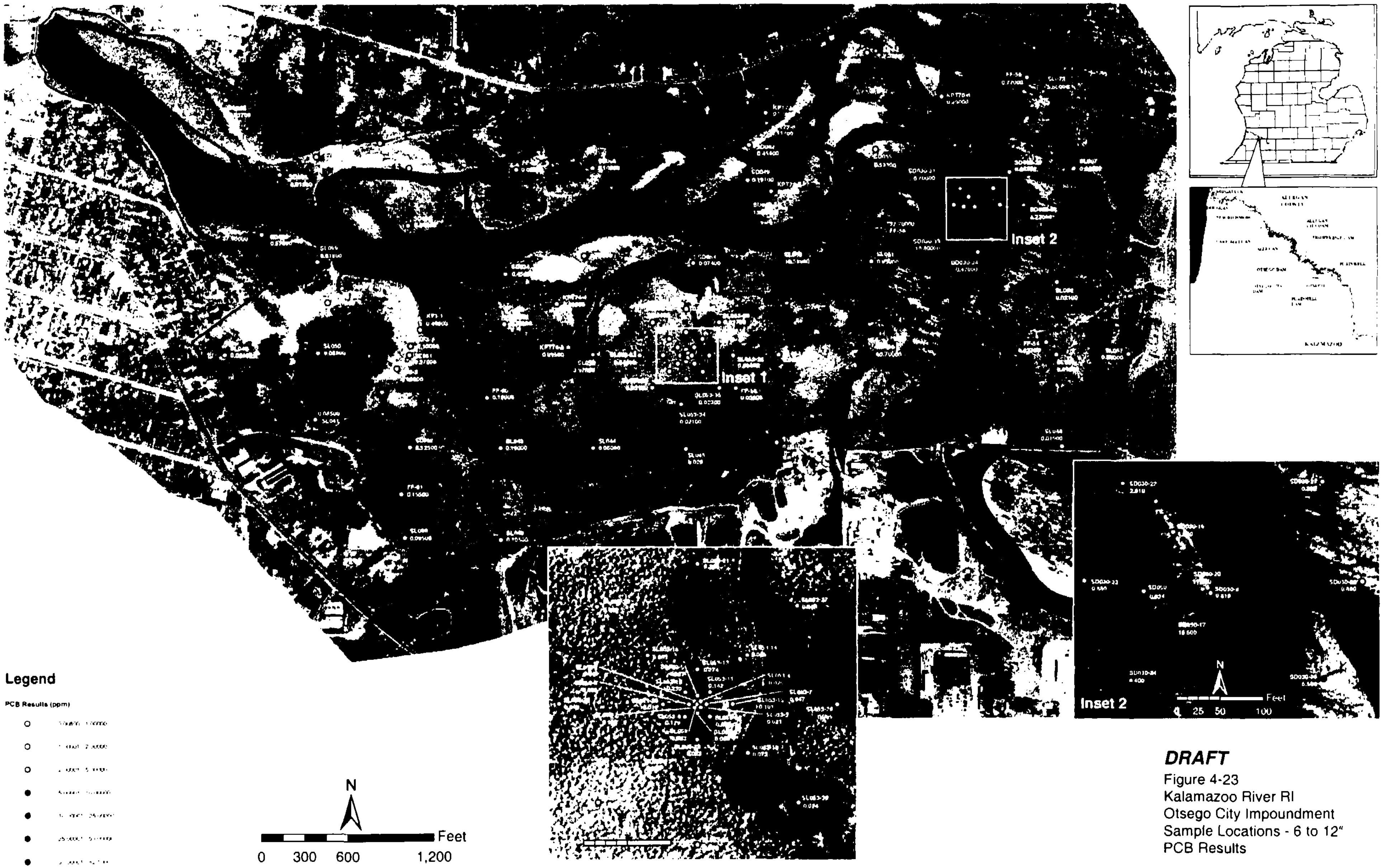

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Figure 4-23
Kalamazoo River RI
Otsego City Impoundment
Sample Locations - 6 to 12"
PCB Results

CH2MHILL

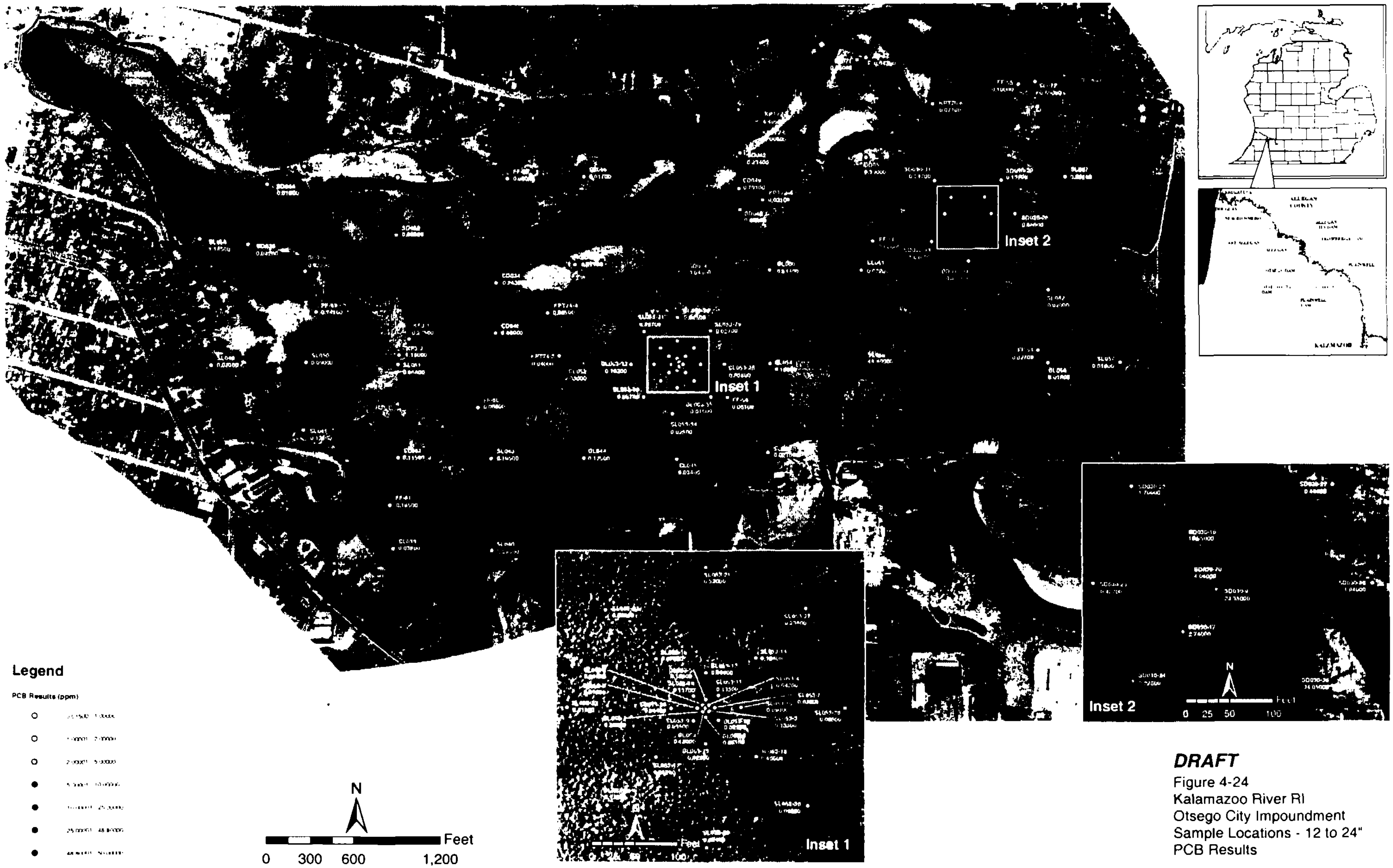

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Figure 4-24
Kalamazoo River RI
Otsego City Impoundment
Sample Locations - 12 to 24"
PCB Results

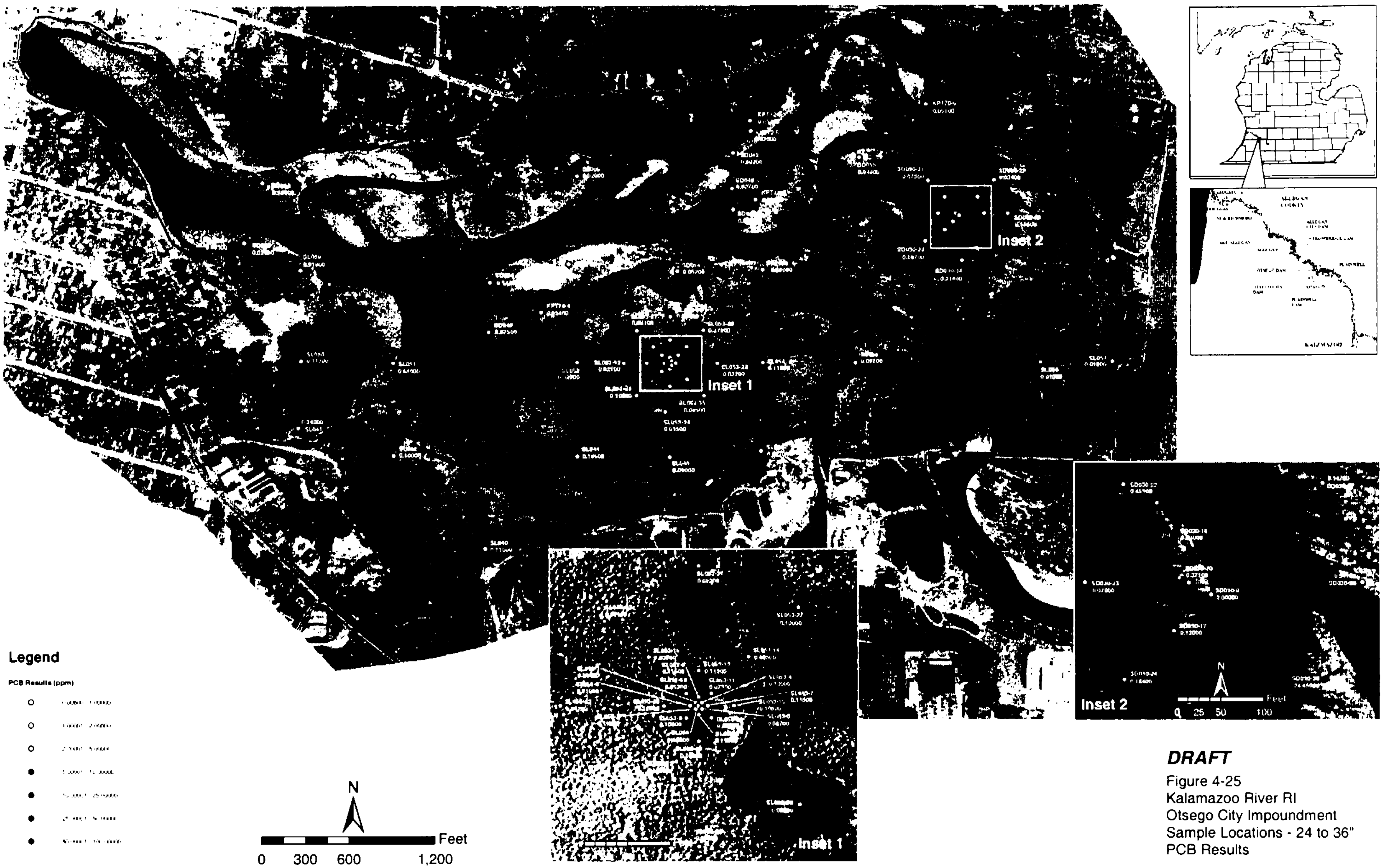

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Figure 4-25
Kalamazoo River RI
Otsego City Impoundment
Sample Locations - 24 to 36"
PCB Results

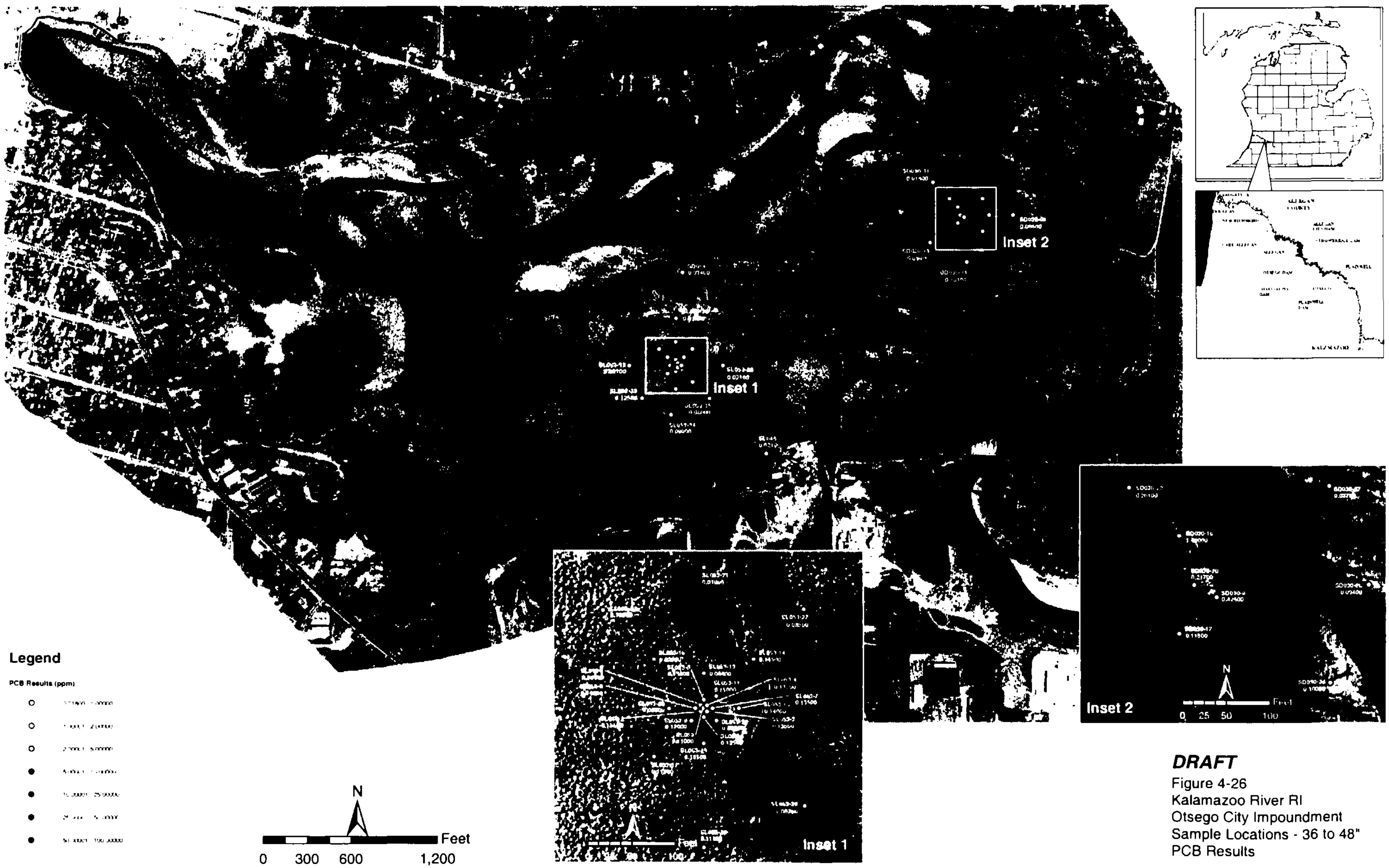

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Figure 4-26
Kalamazoo River RI
Otsego City Impoundment
Sample Locations - 36 to 48"
PCB Results

CH2MHILL

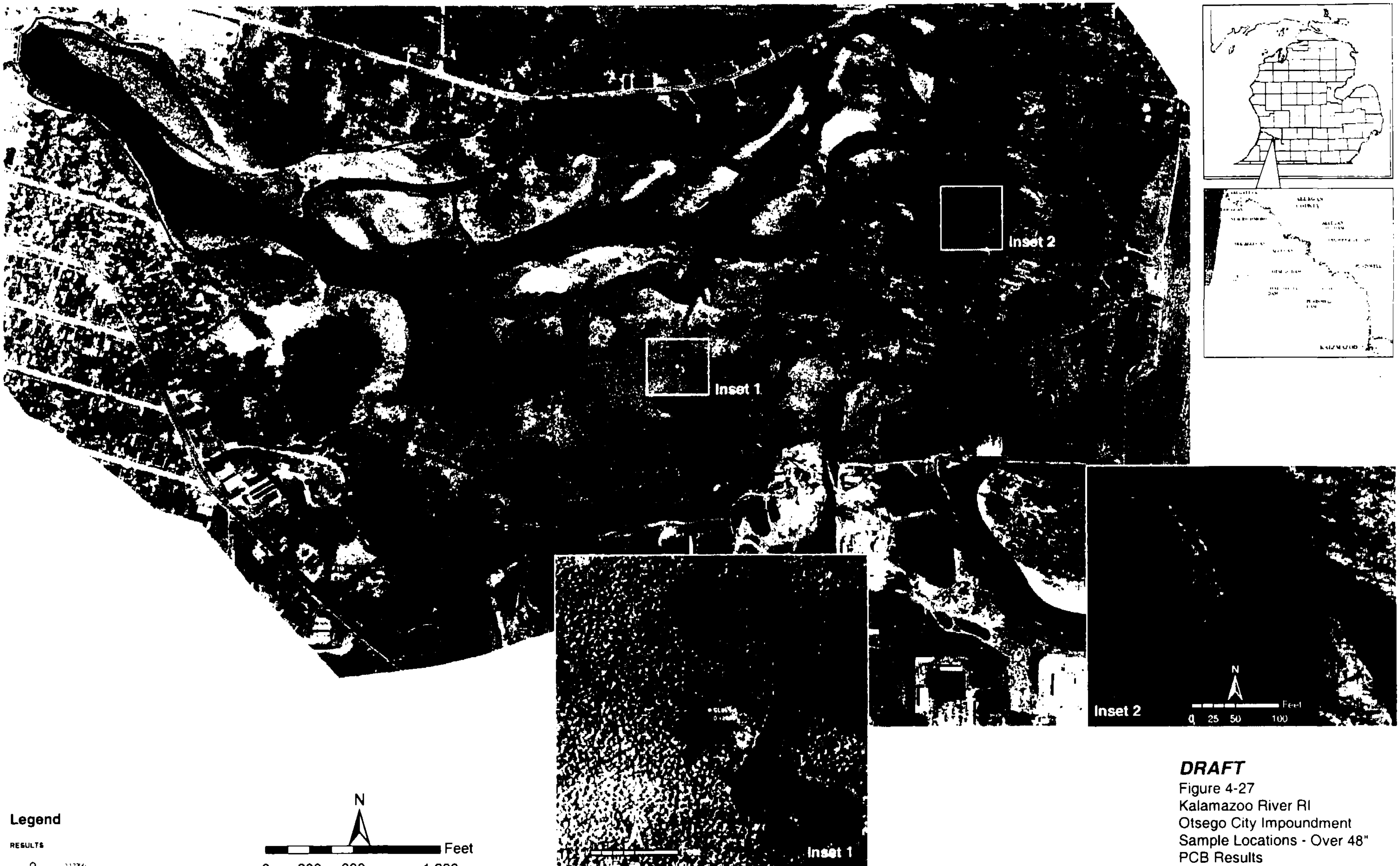

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Figure 4-27
Kalamazoo River RI
Otsego City Impoundment
Sample Locations - Over 48"
PCB Results

CH2MHILL

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Figure 4-30
Kalamazoo River RI
Plainwell Impoundment
Maximum PCB Results Per Location

CH2MHILL

Figure 4-28
Kalamazoo River RI
Floodplain Soils - Plainwell and Otsego City Impoundments
Cumulative Frequency Distribution of PCB Concentrations

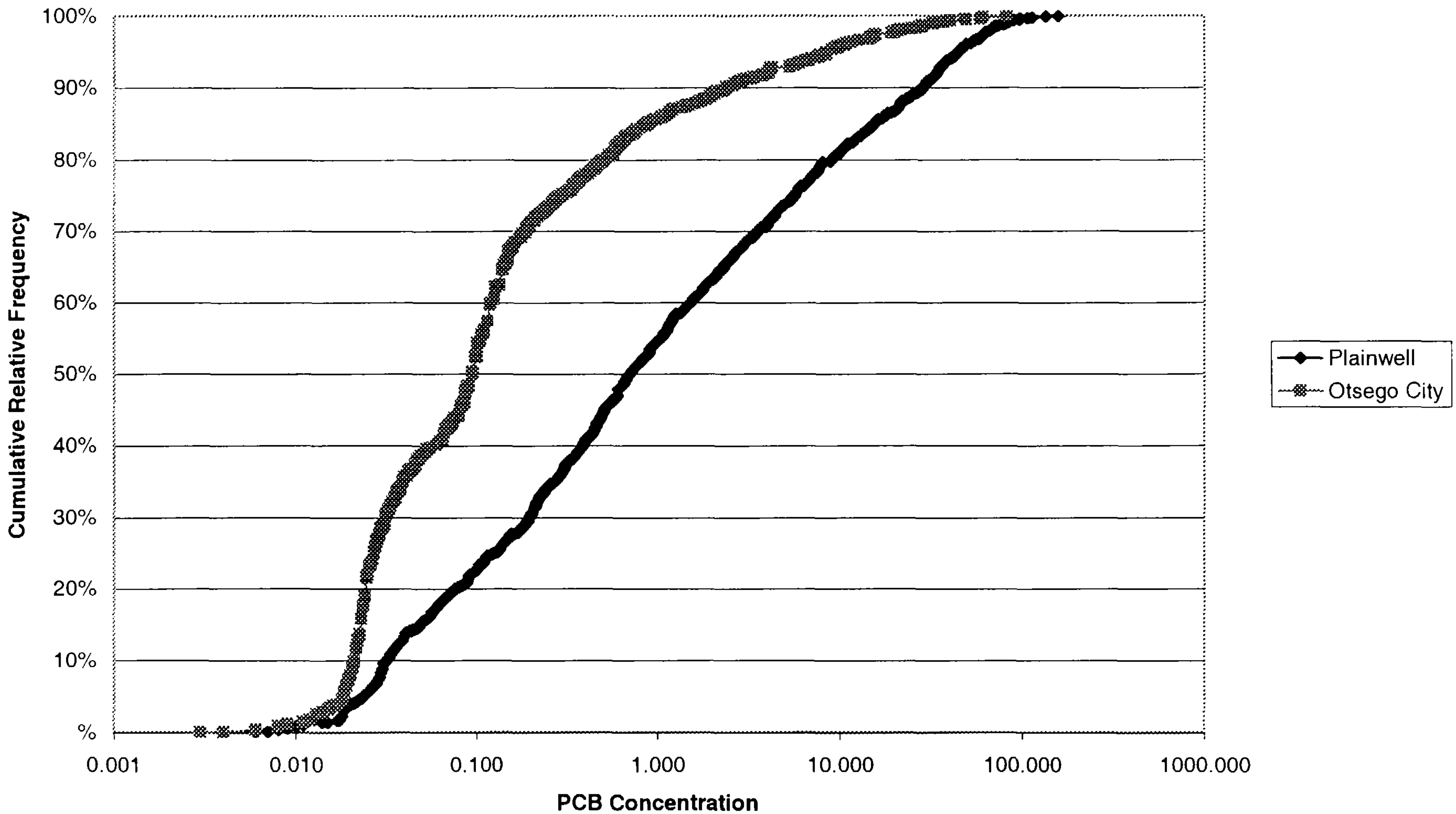

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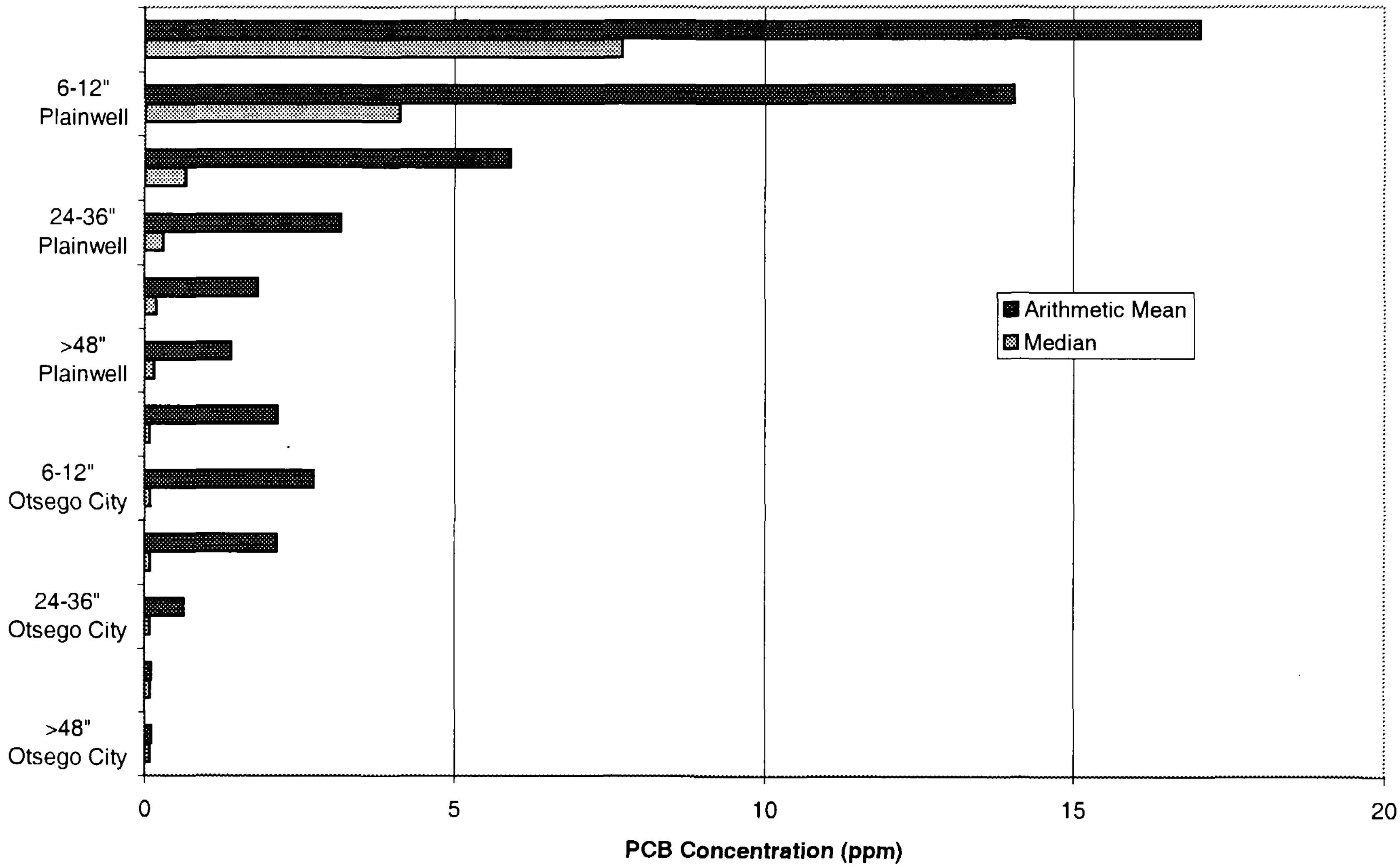
Figure 4-29
Kalamazoo River RI
Floodplain Soils - Plainwell and Otsego City Impoundments
Average PCB Concentration by Depth



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Legend

o Maximum PCB Result

N

Feet
0 300 600 1,200

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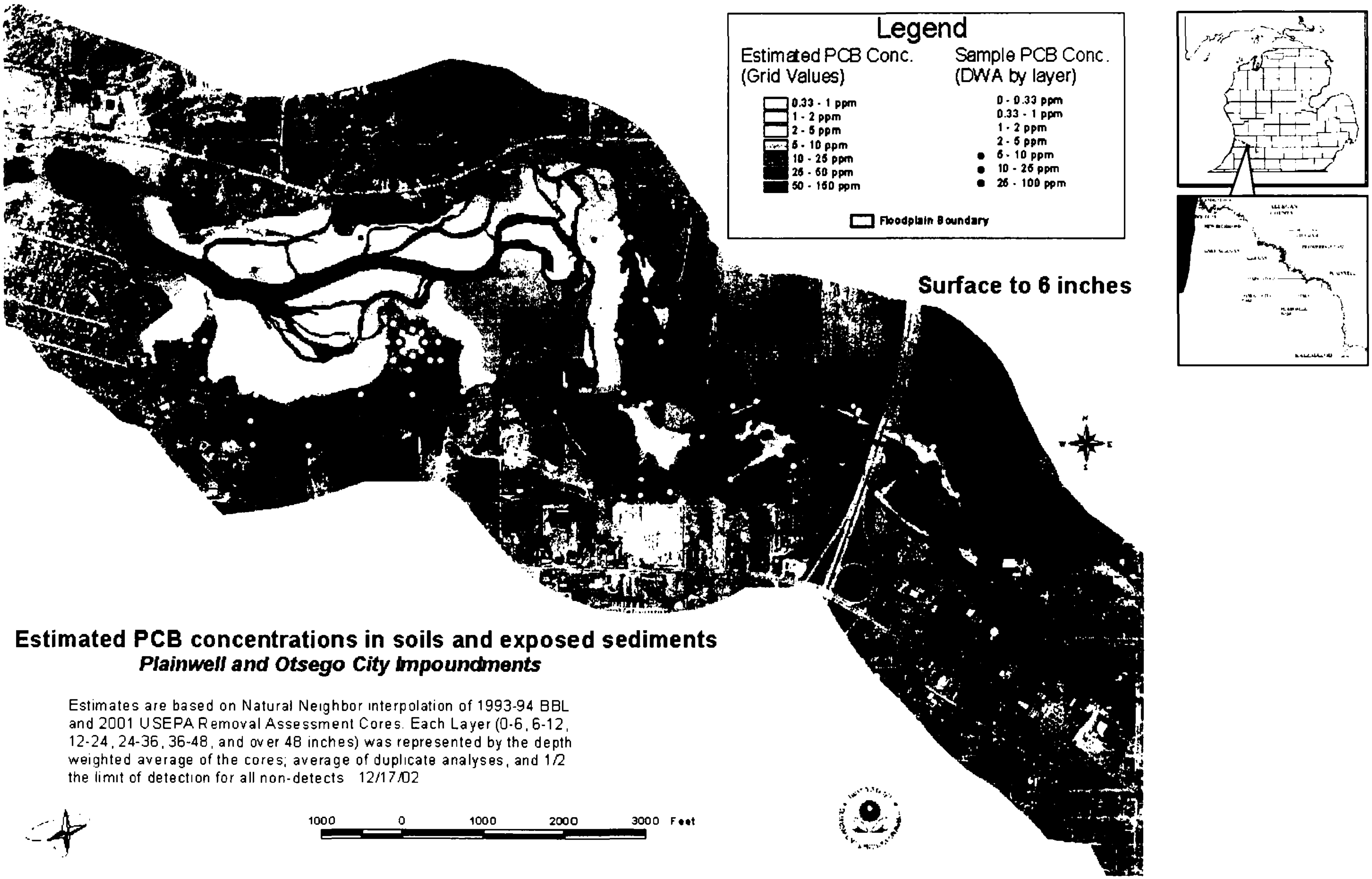
Figure 4-31
Kalamazoo River RI
Otsego City Impoundment
Maximum PCB Results Per Location

CH2MHILL



Estimated PCB concentrations in soils and exposed sediments

Plainwell and Otsego City Impoundments

Estimates are based on Natural Neighbor interpolation of 1993-94 BBL and 2001 USEPA Removal Assessment Cores. Each Layer (0-6, 6-12, 12-24, 24-36, 36-48, and over 48 inches) was represented by the depth weighted average of the cores; average of duplicate analyses, and 1/2 the limit of detection for all non-detects 12/17/02

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Figure 4-33
Kalamazoo River RI
Plainwell and Otsego City Impoundments
USEPA FIELDS PCB Contours
0-6"

Figure 4-32
Kalamazoo River RI
Floodplain Soils - Plainwell and Otsego City Impoundments
Cumulative Detection Frequency of PCB Concentrations

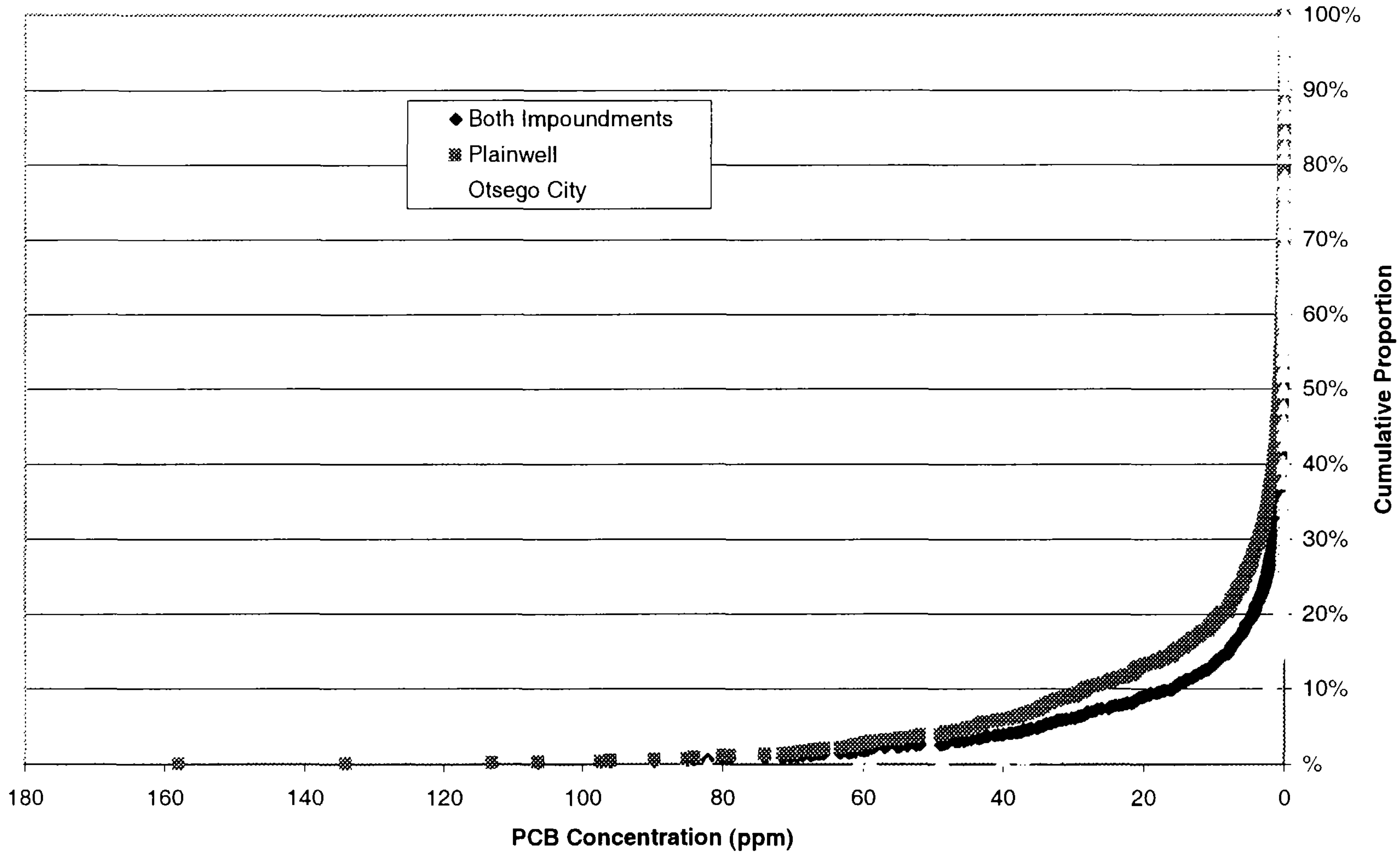

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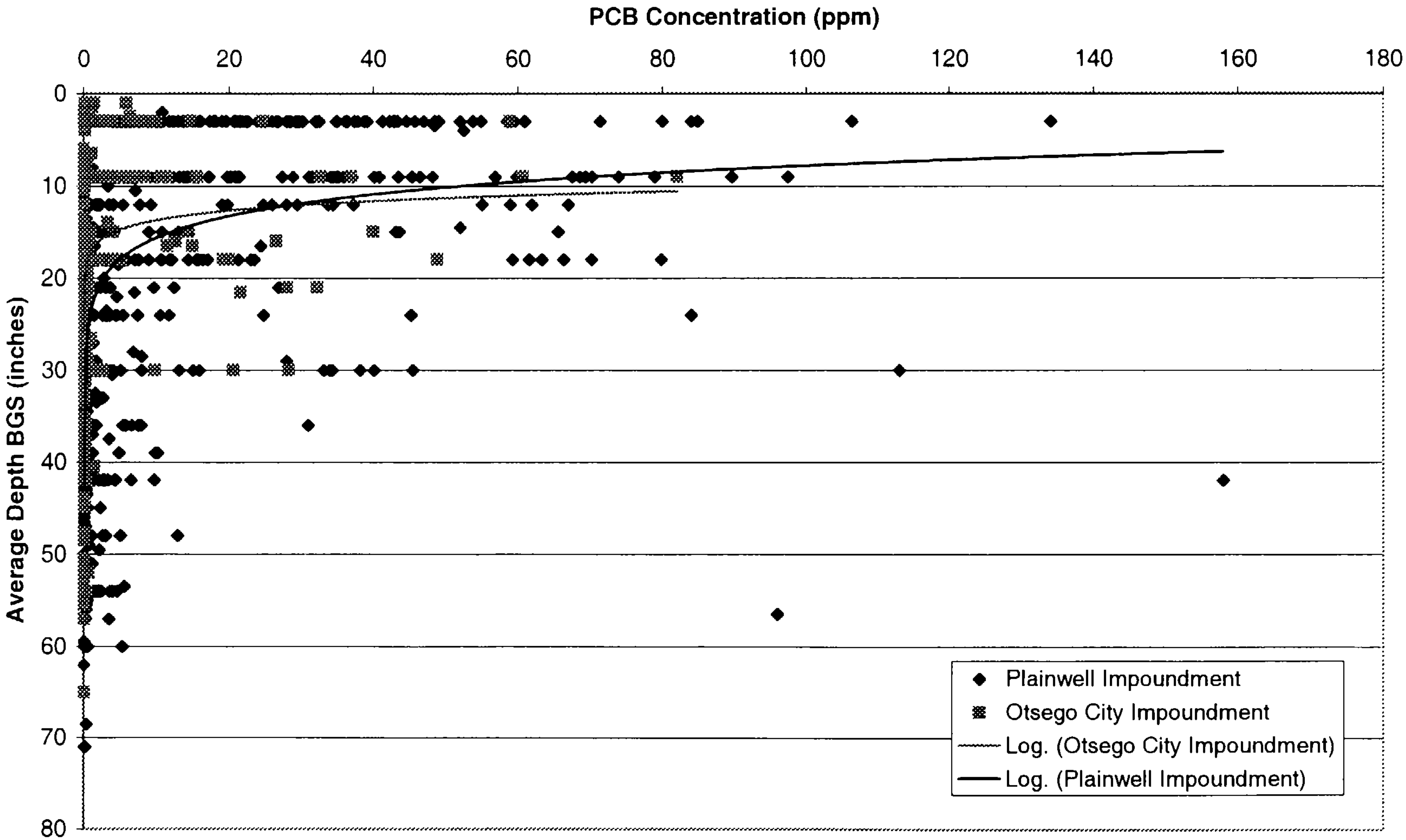
Figure 4-39
Kalamazoo River RI
Floodplain Soils - Plainwell and Otsego City Impoundments
PCB Concentration vs. Depth



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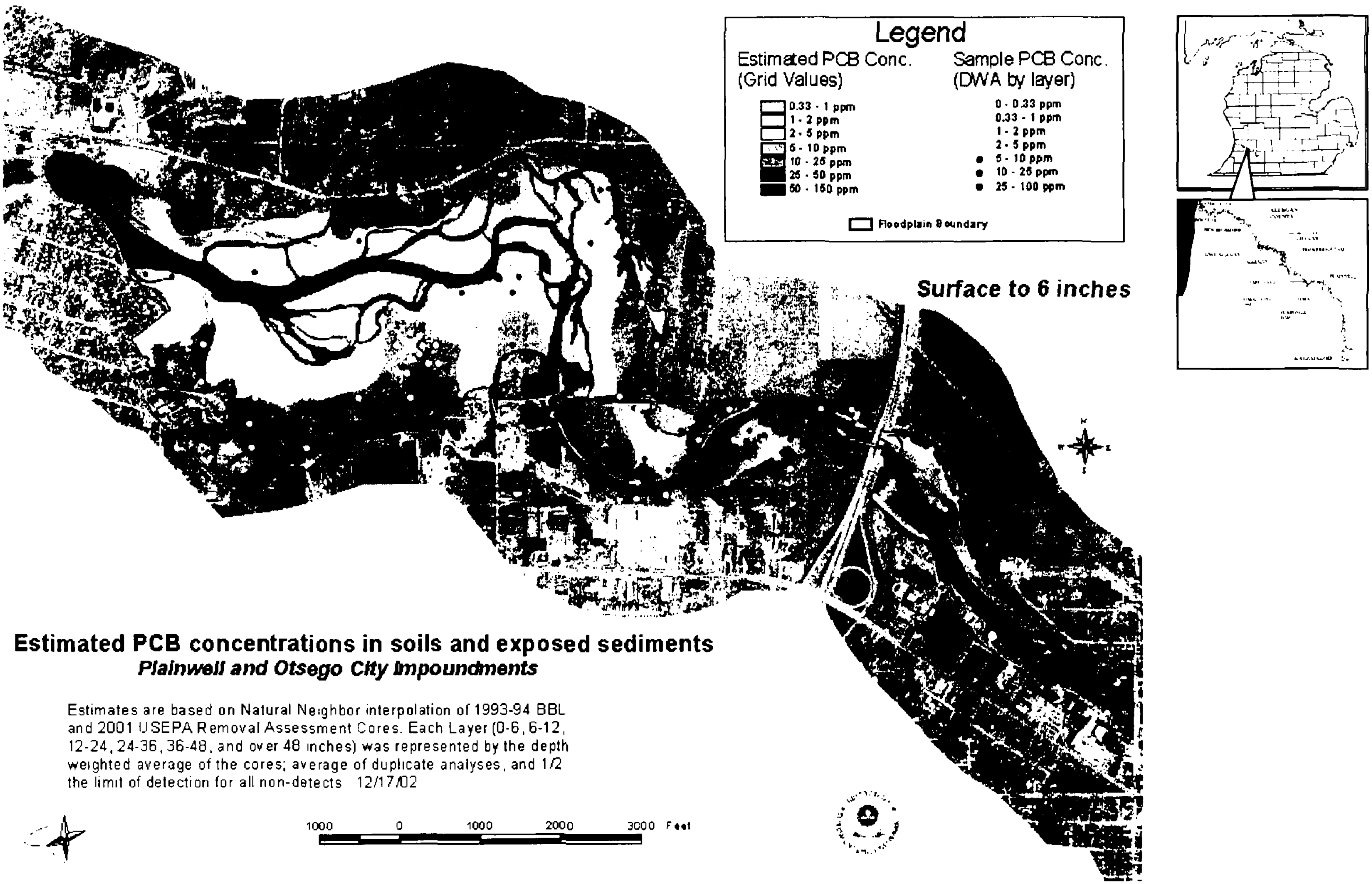

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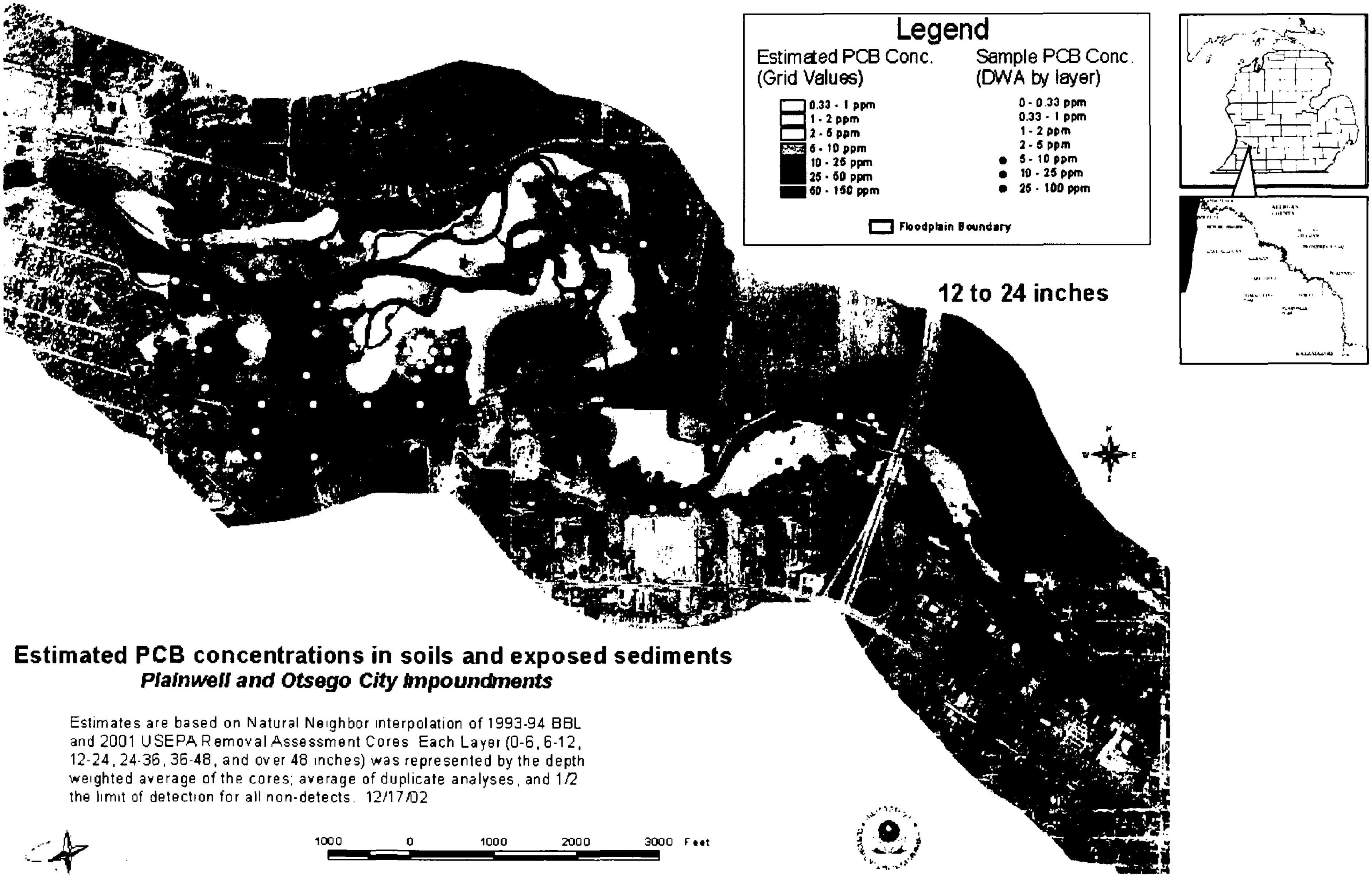
Figure 4-34
Kalamazoo River RI
Plainwell and Otsego City Impoundments
USEPA FIELDS PCB Contours
6-12"



Estimated PCB concentrations in soils and exposed sediments

Plainwell and Otsego City Impoundments

Estimates are based on Natural Neighbor interpolation of 1993-94 BBL and 2001 USEPA Removal Assessment Cores. Each Layer (0-6, 6-12, 12-24, 24-36, 36-48, and over 48 inches) was represented by the depth weighted average of the cores; average of duplicate analyses, and 1/2 the limit of detection for all non-detects. 12/17/02

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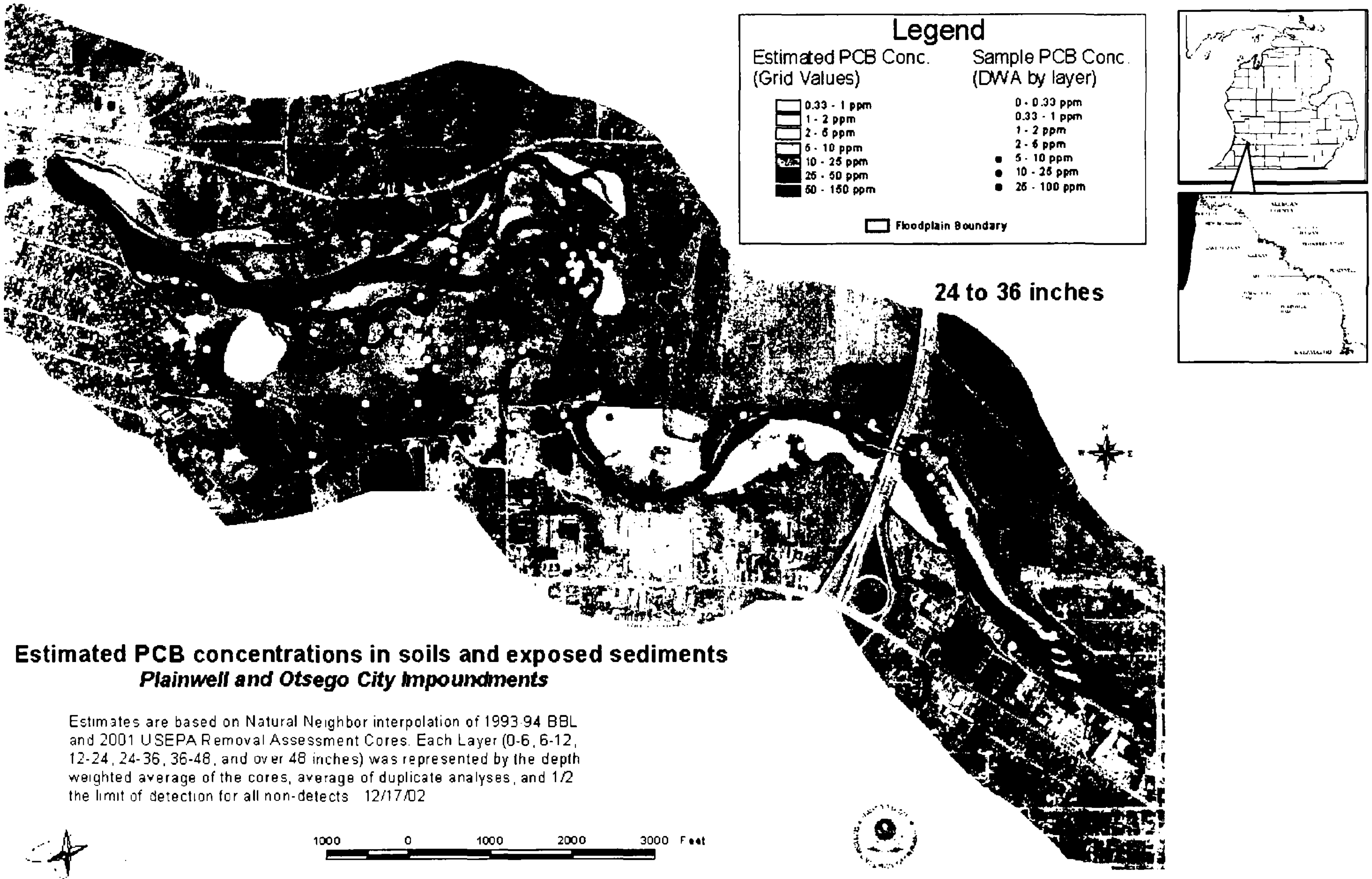
Figure 4-35
Kalamazoo River RI
Plainwell and Otsego City Impoundments
USEPA FIELDS PCB Contours
12-24"



Estimated PCB concentrations in soils and exposed sediments

Plainwell and Otsego City Impoundments

Estimates are based on Natural Neighbor interpolation of 1993-94 BBL and 2001 USEPA Removal Assessment Cores. Each Layer (0-6, 6-12, 12-24, 24-36, 36-48, and over 48 inches) was represented by the depth weighted average of the cores, average of duplicate analyses, and 1/2 the limit of detection for all non-detects. 12/17/02

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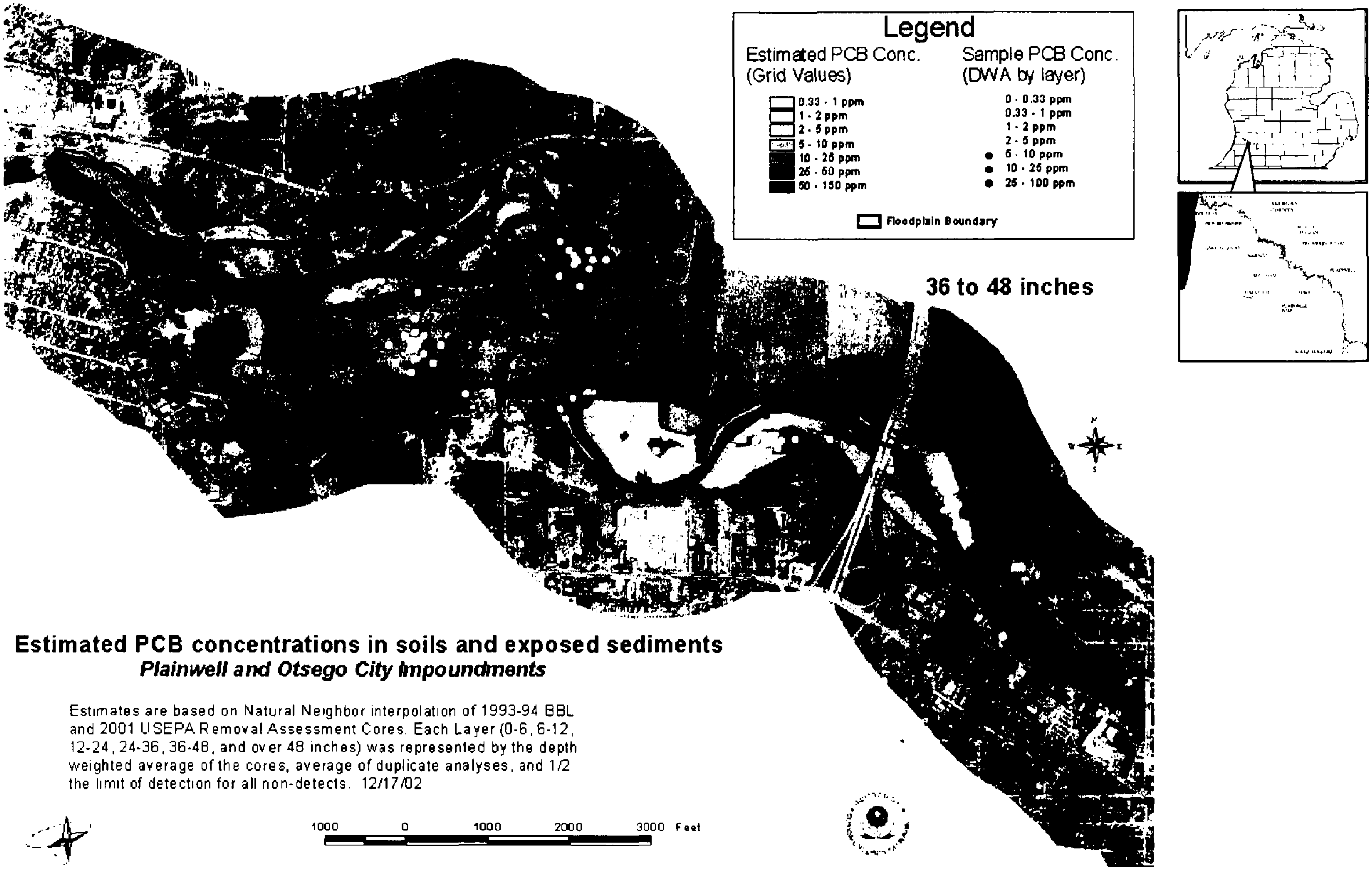
Figure 4-36
Kalamazoo River RI
Plainwell and Otsego City Impoundments
USEPA FIELDS PCB Contours
24-36"



Estimated PCB concentrations in soils and exposed sediments

Plainwell and Otsego City Impoundments

Estimates are based on Natural Neighbor interpolation of 1993-94 BBL and 2001 USEPA Removal Assessment Cores. Each Layer (0-6, 6-12, 12-24, 24-36, 36-48, and over 48 inches) was represented by the depth weighted average of the cores, average of duplicate analyses, and 1/2 the limit of detection for all non-detects. 12/17/02

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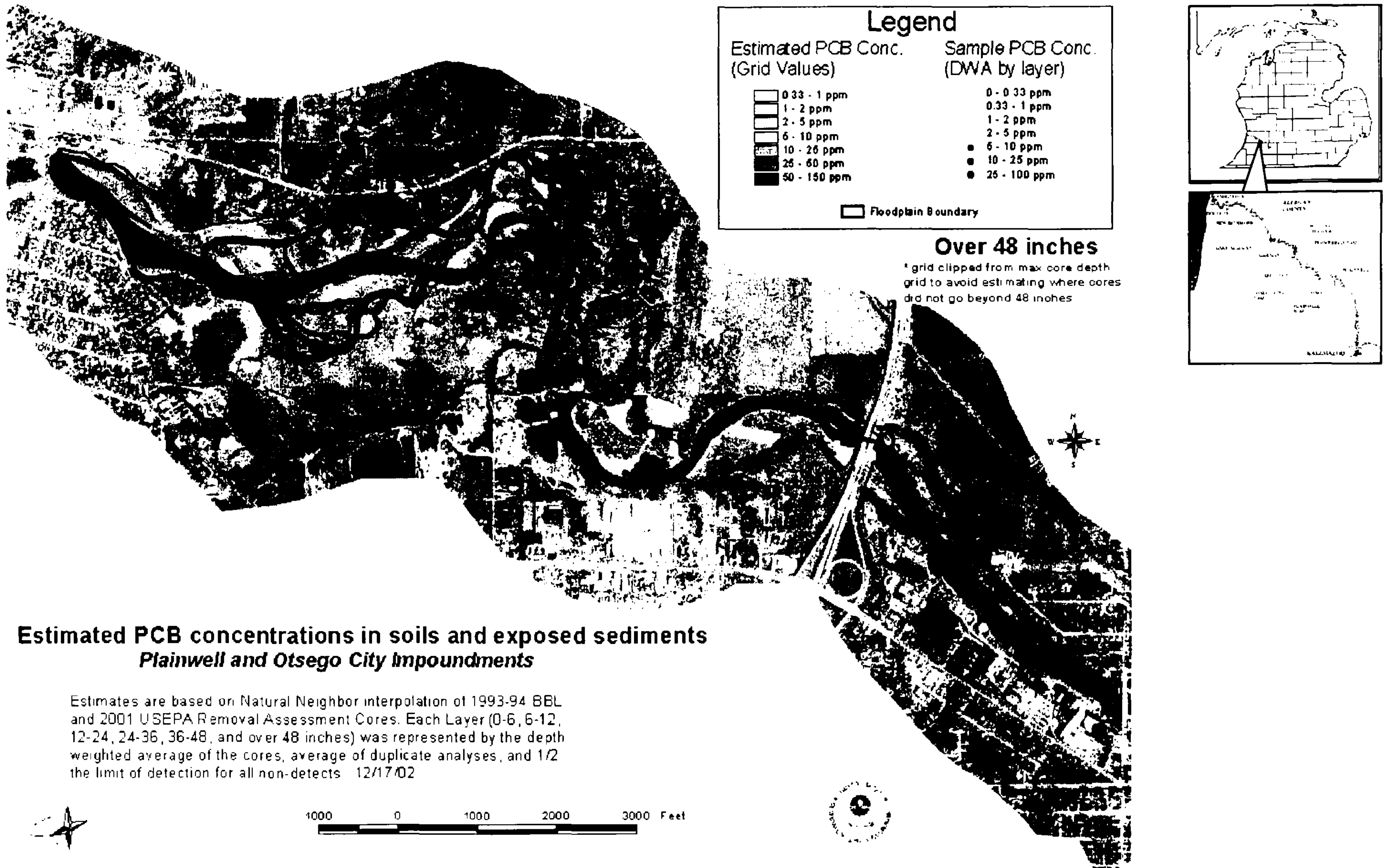
Figure 4-37
Kalamazoo River RI
Plainwell and Otsego City Impoundments
USEPA FIELDS PCB Contours
36-48"



Estimated PCB concentrations in soils and exposed sediments
Plainwell and Otsego City Impoundments

Estimates are based on Natural Neighbor interpolation of 1993-94 BBL and 2001 USEPA Removal Assessment Cores. Each Layer (0-6, 6-12, 12-24, 24-36, 36-48, and over 48 inches) was represented by the depth weighted average of the cores, average of duplicate analyses, and 1/2 the limit of detection for all non-detects. 12/17/02

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Figure 4-38
Kalamazoo River RI
Plainwell and Otsego City Impoundments
USEPA FIELDS PCB Contours
>48"

Figure 4-40
Kalamazoo River RI
Floodplain Soils - Plainwell and Otsego City Impoundments
PCB vs. TOC

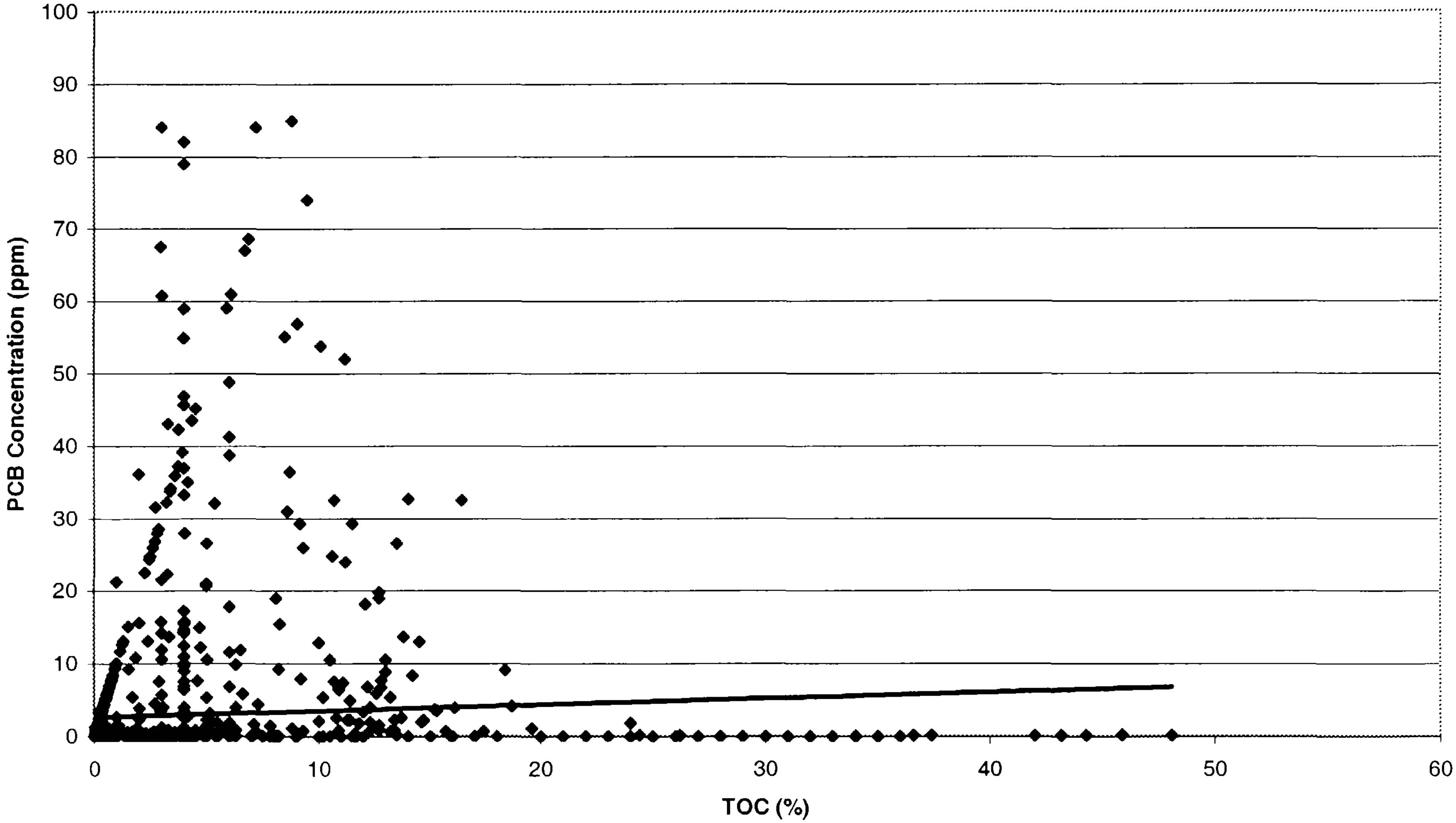

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Figure 4-41
Kalamazoo River RI
Floodplain Soils - Plainwell and Otsego City Impoundments
PCB vs. % Solids

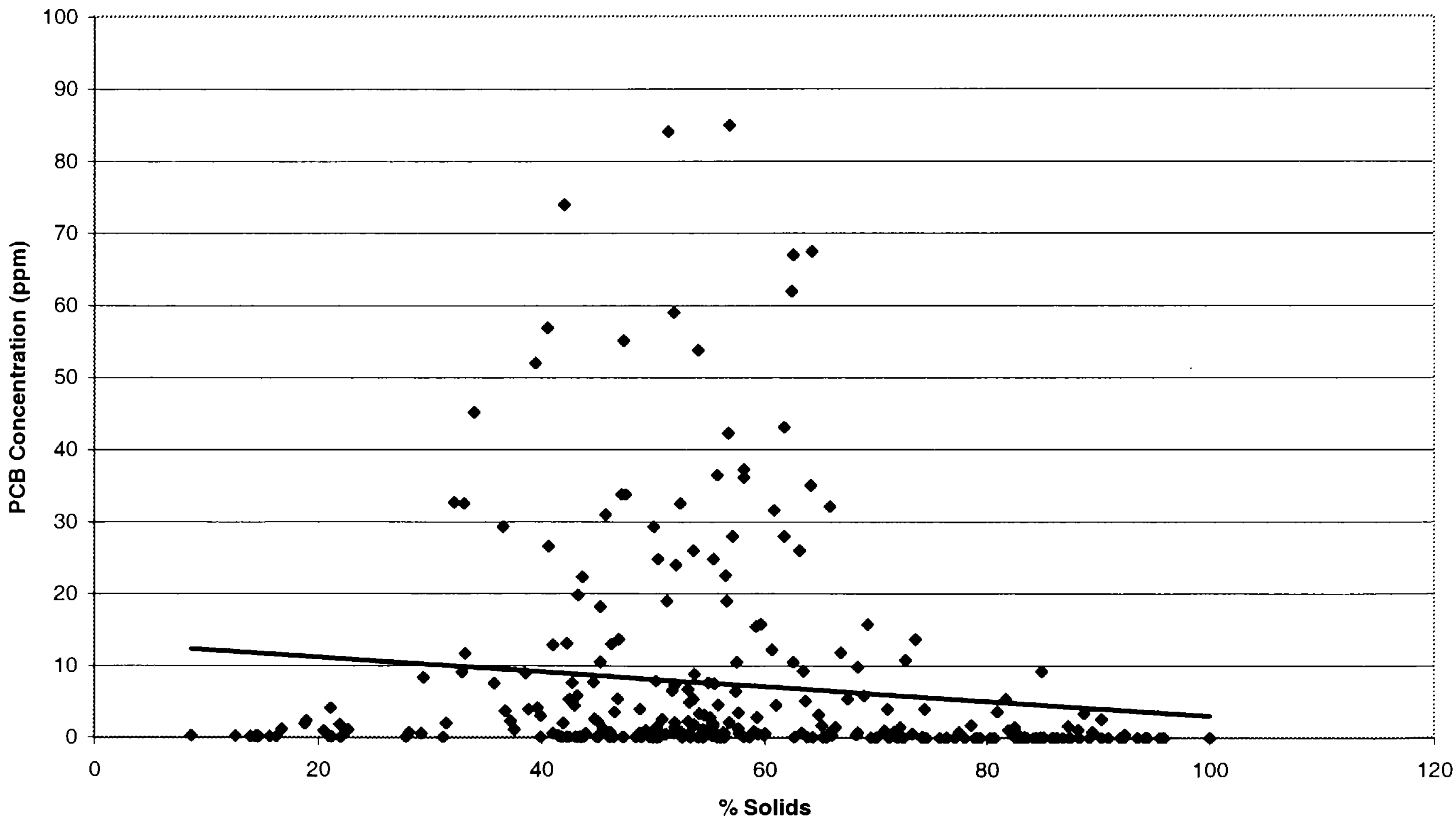

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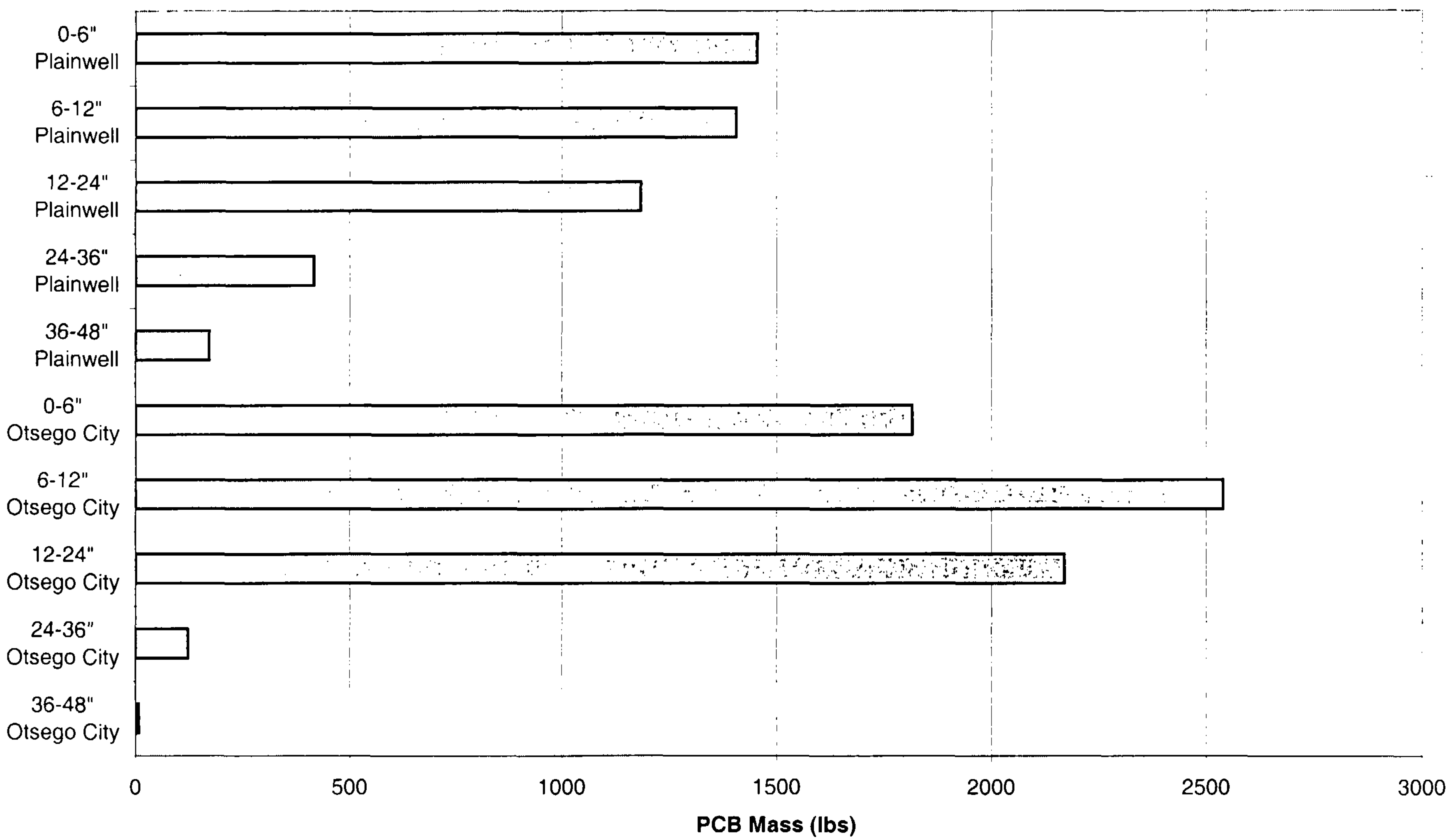
Figure 4-42
Kalamazoo RI
Floodplain Soils - Plainwell and Otsego City Impoundments
PCB Mass



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SECTION 5

Contaminant Fate and Transport

This section contain an assessment of the fate and transport mechanisms affecting the persistence and movement of PCBs to and from the floodplain soils of the Plainwell and Otsego City impoundments. The evaluations of physical and chemical data presented in Section 4 and data from other studies were used to assess the fate and transport of PCBs.

The sources and mechanisms of PCB loading into the floodplain soils are discussed in Section 5.1. Section 5.2 discusses the trends in PCB concentrations in the floodplain soil since BBL conducted the first intensive sampling effort in 1993 (BBL 2000a) and USEPA's more recent sampling (Weston 2002). Section 5.3 discusses the potential migration pathways and transport mechanisms of the PCB-contaminated floodplain soils, including erosion into the Kalamazoo River. A conceptual site model is described in Section 5.4. Section 5.5 summarizes the potential effects of dam removal.

5.1 Sources and Mechanisms of PCB Loading to Floodplain Soils

PCBs historically released into the Kalamazoo River have accumulated in the sediment bed and adjacent floodplain soils. Sources of PCBs detected in the Kalamazoo River include both point and nonpoint sources. Point sources include direct discharges from discrete sources, such as wastewater effluent and publicly owned treatment works. Many PCBs in the river resulted from the discharge of wastes from paper deinking processes during the recycling of carbonless copy paper. Examples of nonpoint sources include upstream urban storm runoff and upstream PCB sediment deposits.

Sediment deposition behind the Plainwell and Otsego City dams accounts for many PCBs in those parts of the floodplain previously below water. Another primary mechanism responsible for the presence of PCBs in the floodplain soils is inundation during high river flow events. These primary mechanisms of PCB transport into the floodplain soils, as well as secondary mechanisms, are discussed below.

5.1.1 Sediment Exposure Following Water Level Drawdown

Flow in the Kalamazoo River has been affected by numerous former and existing dams that slowed the river flow velocity upstream of the dams. The river water typically contains fine suspended sediment. Decreased flow velocity near the dams has facilitated sediment deposition behind them. The impounded areas tended to accumulate more fine sediments rich in natural organic matter (BBL 2000a). Water and sediment continue to be impounded even though some dams have been removed down to their sill levels.

Because the impounded areas contain fine-grained sediments, they also contain higher levels of PCBs. The impounded areas submerged by the river water acted as depositional areas for the PCB-contaminated sediments the river transported from upstream areas. Following the drawdown of water levels in the Otsego City impoundment area in the 1960s and the Plainwell impoundment area in the 1970s, some sediments impounded behind the dams were transported downstream due to the increased river flow velocity immediately following drawdown. However, much of the impounded area was not eroded and transported downstream. As water levels behind the dams were lowered (2 to 4 feet within the Otsego City impoundment, 5 to 10 feet within the Plainwell impoundment), previously inundated sediment was exposed. The exposed areas now comprise much of the floodplain soils. Vegetation has since grown in the exposed areas above the waterline (BBL 2000a).

Elevated PCB concentrations in floodplain soils have been observed in the impounded areas behind the dams. The spatial and vertical extent of PCB contamination within the floodplain soils of the Plainwell and Otsego City impoundments is discussed in Section 4.

5.1.2 Floodplain Inundation and PCB Transport

The physical characteristics of the Kalamazoo River are a primary factor in the fate and transport of PCBs contained within the instream sediments. PCBs have been documented as being present in sediments as far upstream of the Plainwell impoundment area as Morrow Lake. Previous reports estimated that 10,700 pounds (4,870 kg) of PCBs are contained within the instream sediments of the Kalamazoo River between (and including) Morrow Lake and the Otsego City Dam (BBL 2000a). The PCB mass was likely greater in the past. Much of the PCB mass once contained within the aquatic sediments of the river is now in the floodplain soils. Studies have estimated that the PCB mass in the former impoundments is comparable to the total mass found in the existing impoundments, but up to 95 percent of the PCB mass found in the floodplain soils were instream sediments that are no longer submerged (BBL 2000a). An estimated 11,750 pounds of PCBs reside in the floodplain soils of the Plainwell and Otsego City impoundment areas alone (see Section 4).

The PCBs in the Kalamazoo River sediments have been and continue to be a nonpoint source of contamination. When river flows are high, the PCB-containing sediments are scoured, suspended in the water column, and transported downstream. River water containing PCBs (both dissolved and adhering to suspended solids) overflows the riverbanks when flows are high, causing the PCB-containing sediments in the water column to be deposited on the floodplain soils. Evaluation of the surface elevation contours of the floodplains within the Plainwell and Otsego City impoundments shows that the floodplain is relatively flat except for the riverbanks. When river stages are high, large parts of the floodplain may be inundated.

Some PCBs in the floodplain soils of the Plainwell and Otsego City impoundments arrived during the high flow events that followed the drawdown of water levels in the 1960s and 1970s. The lowering of the water levels and the demolition of the superstructures of the Plainwell Dam between 1985 and 1986 resulted in the erosion, transport, and redistribution of some lacustrine sediments that had been impounded behind the dams (USGS 2002). Upon drawing down the water level behind the dams and removing the Plainwell Dam to its sill level, a large flow of river water containing suspended sediments that had been impounded behind the dams likely flowed quickly downstream. Some flows overtopped the riverbanks, depositing PCB-containing sediments on the soils of the adjacent floodplain.

The presence of PCBs in relation to the river flow and the PCB loading from Morrow Lake has been evaluated. The PCB flux to the Kalamazoo River from upstream sources (including

Morrow Lake) is estimated to be 5.7 pounds (2.6 kg) per year (BBL 2002). The average flow when PCBs were detected in the water column samples was 1,250 cfs compared to an average flow of 1,020 cfs for samples with nondetectable PCB concentrations (based on USGS flow data from the Comstock sampling location). Using the 2001 average daily flow data from the Comstock gauge, average flows exceeded 1,250 cfs on 144 of 365 days. Conversely, average daily flows were less than 1,020 cfs on 122 days in 2001. Therefore, the potential for PCBs in the water column to be transported to the floodplain was likely, and continues, to exist during high river flow periods.

5.1.3 Other Sources of PCBs to Floodplain Soils

5.1.3.1 Upstream and Adjacent Sources

Other sources have contributed PCBs to the Kalamazoo River upstream of the Otsego City Dam, potentially affecting the floodplain soils of the Plainwell and Otsego City impoundments. Those sources include former and current industrial facilities, publicly owned treatment works, and inactive waste sites upstream of (or adjacent to) the impoundments.

PCB loadings from industrial facilities have been greatly reduced through various response actions. Completed remedial activities include consolidating residuals into landfills, capping and closing landfills, removing material from the sediment beds immediately adjacent to some OUs, and removing sediment from the former Bryant Mill Pond. Permitting and pollution-control programs also have led to significant decreases of PCB loadings to the Kalamazoo River (BBL 2000a). Nevertheless, historical loadings of PCBs from these sources may have been significant. Contour maps show a plume of PCB contamination in the floodplain soils extending from the 12th Street Landfill within the Otsego City impoundment. This shows that erosion or runoff from the 12th Street Landfill have contributed PCBs to the adjacent floodplain soils.

5.1.3.2 Atmospheric Deposition

Due to the ubiquitous nature of PCBs, atmospheric deposition has been suggested as a source of PCBs to many land and water bodies. Although atmospheric deposition is a source of PCBs to the floodplain soils of the Plainwell and Otsego City impoundments, the amount of PCBs in floodplain soils due to atmospheric deposition is negligible compared to that from other sources. No air sampling data are available from within the Plainwell and Otsego City impoundments.

To illustrate, theWDNR estimated that atmospheric deposition annually contributed 1,400 to 2,200 pounds of PCBs to Lake Michigan. The surface area of Lake Michigan is 57,800 km^2 (WDNR 2002). In comparison, the surface area of the Plainwell and Otsego City impoundments total 2.05 km^2. Using the relative area and assuming equivalent atmospheric PCB concentrations, the annual atmospheric deposition of PCBs to the Plainwell and Otsego City impoundments would be 0.05 to 0.08 pound per year.

5.2 PCB Concentration Trends

The dataset for PCBs in floodplain soils comprises more than 1,700 samples collected from the Plainwell and Otsego City impoundments over a 9-year period. Floodplain soil sampling was conducted between 1993 and 1994 as part of an RI/FS effort conducted by BBL on behalf of the KRSG. BBL conducted additional sampling in 1997 and 2000 to update the RI/FS. The dataset includes samples collected by CDM on behalf of the MDEQ as part of long-term monitoring of the Kalamazoo River. Weston also conducted sampling on behalf of USEPA as part of a removal assessment in 2001.

The floodplain soil data show that PCB concentrations in floodplain soils have remained relatively unchanged or may have increased in some cases. Figure 4-2 plots PCB concentrations by sampling date and also shows surficial PCB concentration trends. No increasing or decreasing PCB concentration trends are apparent when comparing data from all depth intervals between 1993 and 2001. PCB concentrations in the upper 6 inches of floodplain soil show an increase between the same time period, suggesting a potential continuing source of PCBs to floodplain soils. However, this observed trend may be an artifact of different targeted sampling areas and sampling objectives of the individual investigations. Colocated samples (e.g., samples obtained from the same location over time) were not found when evaluating the dataset.

Although other reports document the presence of ongoing natural processes that are reducing PCB levels in other environmental media, this is not observed in the floodplain soils based upon the current PCB data. Previous studies have concluded that, in general, levels of PCB in surficial sediments, surface water, and fish have declined significantly over the last 2 decades (BBL 2000a). PCB trends in floodplain soils were not discussed. The decreased PCB levels in surficial sediments, surface water, and fish were attributed to the effects of natural processes ongoing in the Kalamazoo River that decrease PCB concentrations and bioavailability.

One natural process for instream sediments involves the burial of sediments containing high levels of PCBs by a layer of cleaner sediments. This removes the PCBs from the uppermost bioavailable layer of sediments. Unlike submerged sediments, the floodplain soil data show that maximum PCB concentrations remain in the surficial layer of sediment and are not subject to the same natural processes as the instream sediments. Because elevated levels of PCBs remain in the surficial floodplain layers, they remain bioavailable for terrestrial biota.

5.3 Migration Pathways and Transport from Floodplain Soils

This section summarizes the chemical and physical properties of PCBs and discusses their effects on the fate and transport processes in the floodplain soils. The chemical and physical fate and transport processes are discussed separately below.

5.3.1 Chemical Transport Processes

Chemical transport processes for the PCBs in the floodplain soils include desorption to the interstitial pore water, volatilization into the atmosphere, adsorption to soil particles, and uptake by plants and animals. Table 5-1 summarizes some of the physicochemical factors of the main PCB Aroclors detected in the floodplain soils of the Plainwell and Otsego City impoundments. The factors listed in Table 5-1 are commonly associated with the fate and transport of PCBs in the environment.

TABLE 5-1
Fate and Transport Physicochemical Factors

PCB	Water Solubility (mg/L)	Henry's Law Constant (atm-m^3/mol)	K_{oc} (mL/g)	K_{ow} (mL/g)
PCBs (General values)	3.10×10^{-2}	1.07×10^{-3}	5.30×10^{5}	1.10×10^{6}
Aroclor-1242	2.40×10^{-1}	5.60×10^{-4}	Not available	1.29×10^{4}
Aroclor-1248	5.40×10^{-2}	3.50×10^{-3}	Not available	5.62×10^{5}
Aroclor-1254	1.20×10^{-2}	2.70×10^{-3}	4.25×10^{4}	1.07×10^{6}
Aroclor-1260	2.70×10^{-3}	7.10×10^{-3}	Not available	1.38×10^{7}

References:
EPA document EPA-600/8-90/003.
ATSDR Toxicological Profile for PCBs 2000.
Erickson 1997.

Water solubility is a measure of the extent to which PCBs partition between soil particles and pore water. The Henry's law constant is the equilibrium distribution of a chemical between air and water and is important when evaluating the potential for contaminant flux to air. The Henry's law constant is dependent on the chemical's solubility. The organic carbon partitioning coefficient (K_{oc}) and octanol-water partition coefficient (K_{ow}) are measures of the degree of chemical sorption to organic matter in soil, sediment, and particulate matter. K_{oc} and K_{ow} are also measures of hydrophobicity. The tendency for PCBs to bioaccumulate is related to its hydrophobicity, since bioaccumulation factors increase with increasing hydrophobicity.

In general, PCBs are not very water soluble, moderately volatile, and, once released into the environment, have an affinity for (and typically partition to) the organic matter in soil, sediment, and biota. PCBs have low water solubilities because of their strong affinity for soil and sediment particles. In a dissolved state, volatilization is an important process for PCB loss. However, volatilization of PCBs is a relatively slow process because of their low aqueous solubilities. Additionally, adsorption to soil or sediment particles significantly decreases the volatilization rate. Lower chlorinated PCBs typically are more subject to volatilization. The main PCB Aroclors detected within the floodplain soils of the Plainwell and Otsego City impoundments were Aroclor-1254 and -1260 (and to a lesser extent, Aroclor-1242 and -1248). These Aroclors typically contain more highly chlorinated PCB compounds. Therefore, volatilization is not likely to be significant loss mechanisms for PCBs in the floodplain soils within the impoundments and the release of PCBs to air is not likely to pose a substantial risk. No air sampling data are available from within the Plainwell and Otsego City impoundments.

5.3.2 Physical Transport Processes

PCBs are ubiquitous in the environment because they adhere readily to organic material in sediment and soils, they tend to bioaccumulate in the fatty tissue of fish and other wildlife, and they degrade very slowly. The fate and transport of PCBs are related primarily to the adsorption to soil or sediment particles or other organic matter. The PCBs adsorbed to the solid particles are predominantly transported within the environment by the physical processes that transport the solid particles.

Prior to the drawdown of the water levels within the impoundments, the transport of the PCBs within the sediments primarily was due to advective transport by the water column. River sediments that contained PCBs were resuspended in the water column and transported downstream to depositional sinks, such as the impoundments. Once water levels in the impoundments were lowered, the process of resuspension and subsequent downstream transport of PCB-containing sediments was reduced, except during high river flow events.

Following the drawdown of water behind the dams, river flow velocities increased, causing the Kalamazoo River to quickly carve a new channel into the soft sediments behind the dams, leaving steep banks of the newly formed floodplain soil as the new stream banks. The impoundments were changed from sediment depositional areas to soil erosional areas with hundreds of acres of newly exposed former sediments constituting the floodplains. The floodplain soil banks in some areas have been and are susceptible to undercutting, erosion, and downstream transport due to increased river velocities; decreased side-slope stability; and potential channel meandering (BBL 2000a).

The current Plainwell impoundment area consists of 129 acres of floodplain soils. The Otsego City Impoundment area consists of 377 acres. The physical transport of soil particles is believed to be the primary transport mechanism for the movement of PCBs within the floodplain soils of the Plainwell and Otsego City impoundments.

The magnitude of PCB loading from the riverbanks of the Plainwell, Otsego, and Trowbridge impoundment areas were estimated previously. Using the PCB data, characteristics of the riverbank conditions, and calculated bank erosion rates, estimates of the mass of PCB entering the river annually from the banks of the former impoundments were made. The erosion rate estimates were derived by comparing transect locations surveyed in 1994 to those resurveyed in 1999 to estimate how much material eroded into the river. Additionally, erosion pins were placed at survey locations in 2000 to measure riverbank loss over time (BBL 2000c).

Using simple calculations and assumptions, an estimated 22 to 220 pounds (10 to 100 kg) of PCBs eroded into the river annually from three former impoundments (Plainwell, Otsego, and Trowbridge) (BBL 2000a). More detailed evaluation of the data refined this estimate to 68 pounds (31 kg) of PCBs eroded into the river from the three former impoundments: 22 pounds (10 kg) from Plainwell, 11 pounds (5 kg) from Otsego, and 35 pounds (16 kg) from Trowbridge (BBL 2000c). More recent analysis estimates that 46 pounds (21 kg) of PCBs have eroded annually from the three former impoundments since the water levels were drawn down in the 1970s (BBL 2001). The erosion of PCB contaminated soils from the Otsego City impoundment were not estimated.

The USGS is modeling the effects of erosional forces on the riverbanks of the Kalamazoo River within the impoundments. The results of that work will be used quantitatively to evaluate the amount of soil eroded from the riverbanks and the associated PCB transported to the Kalamazoo River.

The stability and erodibility of the riverbanks within the impoundments have also been assessed (BBL 2000a). The banks at the impoundments have visually been observed to be sloughing with signs of erosion, providing evidence of ongoing loading of the floodplain soils to the river. Erosion of the riverbanks are due to natural processes (i.e., sloughing, etc.), and are accelerated during high river flow events. Lengths of riverbank that are vertical or nearly vertical and devoid of vegetation have been observed (BBL 2000a). The faces of the banks are susceptible to erosion through direct contact with the river at higher river stages and to undercutting by erosion of underlying noncohesive sediments or soils.

The observation of erosion of the floodplain soils in the river, combined with laboratory results that show that the floodplain soils contain PCBs, confirm that the banks of the river continue to act as a source of PCBs (BBL 2000a). Erosion of the riverbanks results in the downstream transport and redistribution of PCB-containing soils. Once the floodplain soils containing the PCBs are eroded into the river's water column, they are available to be transported in suspension or as bed load to downstream areas by river currents.

Transport processes that affect the floodplain soil that are not subject to the potential erosion differ from those near the river channel. Although the banks of the floodplain soils near the river channel act as a source of PCBs for the river, the remaining areas within the floodplain soil are relatively flat and thickly covered by vegetation. These areas act as a sink for PCB-containing sediments from the river during flooding (BBL 2000a).

5.3.3 Other Transport Processes

Other transport processes that affect the PCBs in the floodplain soils include biodegradation, direct uptake by plants and animals living on and in the floodplain soils, and leaching to groundwater. In general, PCBs are resistant to biodegradation, tend to bioaccumulate in the fatty tissue of organisms, and have a strong affinity for the floodplain soil particles.

5.3.3.1 Biodegradation

The breakdown of PCBs by microorganisms may occur to a limited extent in soils. Some PCB molecules have been shown to be selectively dechlorinated by aerobic or anaerobic bacteria in aquatic environments. Studies have shown that certain PCB compounds can be degraded under aerobic conditions or microbially dechlorinated under anaerobic conditions in aquatic environments (NRC 2001).

Transformations of PCBs can occur in aquatic systems by microbial degradation (in aerobic water columns and surficial sediments), reductive dechlorination (in anaerobic sediments), and metabolism by organisms that take up PCBs. Generally, the less chlorinated congeners are more water soluble, more volatile, and more likely to biodegrade. More chlorinated PCBs are often more resistant to degradation and volatilization and adsorb more strongly to particulate matter (NRC 2001). PCBs typically degrade slowly in the environment, so biodegradation is not considered to be a primary fate and transport process for the PCBs in the floodplain soils.

5.3.3.2 Bioaccumulation

Bioaccumulation is the process by which plants and animals directly or indirectly absorb PCBs. The potential for PCBs to bioaccumulate generally is measured by the K_{ow} partition coefficient. Compounds with high K_{ow} values are more bioaccumulative. In general, PCBs are readily bioaccumulated by organisms and biomagnify up the food chain.

The PCB concentrations in terrestrial biota have been investigated (BBL 2000a). PCB levels were measured in select terrestrial biota (mice and earthworms) to estimate their exposure to the PCBs contained in the floodplain soils. Within the floodplain soils, concentrations of PCB in mice and earthworms were calculated to be 1 to 10 percent of the PCB levels in the soil on or in which the organisms were found. Specifically, within the Plainwell impoundment, PCB concentrations average 0.46 mg/kg in earthworms and 0.092 mg/kg in mice. In comparison, the average PCB concentration of the soils was 6.5 mg/kg. Although the bioaccumulation of PCBs is significant and of concern due to the potential risk to the ecological receptors, its affect on the fate and transport of PCBs in the floodplain soils is believed to be relatively small.

5.3.3.3 Leaching to Groundwater

Leaching of PCBs to groundwater occurs by desorption of the PCBs from the soils to the associated groundwater. Although the solubility of PCBs is relatively low, PCBs contained in soils can leach to the groundwater. However, groundwater contamination within the Plainwell and Otsego City impoundments has not been fully evaluated.

Due to its low aqueous solubility, the potential for groundwater contaminated with PCBs to be transported to the Kalamazoo River is expected to be small. Groundwater flow is anticipated to be toward the Kalamazoo River. The river and shallow aquifer are hydraulically connected, so there is a close relationship between surface water and groundwater flows (BBL 2000a). Groundwater seepage flux to the surface water would need to be determined for a detailed analysis of the groundwater flux potential to the river.

5.4 Conceptual Site Model

The conceptual site model summarizes the significant physical and chemical processes that affect the fate and transport of the PCBs in the floodplain soils of the Plainwell and Otsego City impoundments. It is based on the available data and known and suspected significant environmental fate and transport processes. The conceptual model considers the PCB sources, the affected media, and the potential routes of transport. It describes the transport of PCBs into and out of the floodplain soils of the Plainwell and Otsego City impoundments.

The existing and former dams historically reduced river flows behind them, which resulted in the deposition of sediments and PCBs in the impounded areas upstream of the dams. When the water levels were drawn down behind the dams, the sediments were exposed and now comprise much of the existing floodplain soils. Most of the floodplain continues to act as a depositional sink during floods due its relatively flat nature and level of vegetation. However, the floodplain soils near the river channel are believed to be a significant source of PCBs to the Kalamazoo River due to ongoing erosional forces.

Elevated PCB concentrations have been detected within the floodplain soils in the Plainwell and Otsego City impoundments. The extent of PCB contamination is detailed in Section 4. An estimated 1.7 million cubic yards of floodplain soils containing 11,750 pounds of PCBs are contained within the Plainwell and Otsego City impoundments. PCB levels within the floodplain soils have remained relatively steady over the last 9 years.

Sources of PCBs continue to affect the Kalamazoo River system. PCBs can be transported into and out of the floodplain soils of the Plainwell and Otsego City impoundments. The major transport processes include floodplain inundation when river flows are high and erosion of floodplain soils contained on the banks of the river channel into the Kalamazoo River. To a lesser extent, other PCB transport processes affect the PCBs, including dissolution, volatilization, biodegradation, uptake to plants and animals, and leaching into the groundwater. The degree of risk posed by the PCBs contained within and transported from the floodplain soils is presented in Section 6. Table 5-2 summarizes the PCB mass balance for the floodplain soils of the Plainwell and Otsego impoundments. Conditions in 2050 were chosen arbitrarily to illustrate how the PCB mass may change. The table is intended to illustrate general patterns in the overall PCB mass balance. Actual PCB mass flux may differ substantially from the estimates provided.

TABLE 5-2
Conceptual Model of PCB Mass Balance

Transport Process	Current Conditions in Floodplain Soils	Condition in 2050 Assuming Current Rates
Annual Inundation Deposition from Adjacent and Upstream Sources (lb/yr)	Uncertain but may be limited because upstream PCB mass is estimated at 10,700 lb (assume 5.7 lb/yr)[a]	+270 lb
Annual Atmospheric Deposition (lb/yr)	0.05 to 0.08 lb/yr[b]	+ 3 lb
Annual Loss from Streambank Erosion (lb/yr)	< 46 lb/yr[c] (assume 40 lb/yr)	-1,900 lb
Annual Loss from Biological Uptake, Biodegradation, Volatilization (lb/yr)	Uncertain, assumed to be small	- small mass of PCBs
Annual Loss from Leaching to Groundwater (lb/yr)	Uncertain, assumed to be small	- small mass of PCBs
PCB Mass (lb)	11,750	10,120

Note:
This table is intended to illustrate general patterns in the overall PCB mass balance. Actual PCB mass flux may be substantially different than the estimates provided based on the assumptions used.

[a] BBL estimated PCB fluxes from upstream sources to be approximately 5.7 lb (2.6 kg) per year. It was conservatively estimated that all this mass would be redeposited onto the floodplain soils of the Plainwell and Otsego City impoundments.
[b] See Section 5.1.3.2.
[c] BBL estimated that 46 lb (21 kg) of PCBs erode from the Plainwell, Otsego, and Trowbridge impoundments annually. An estimate of 40 lb of PCBs was used for the annual erosion of PCBs from the Plainwell and Otsego City impoundments.

5.5 Evaluation of the Potential Removal of Existing Dams

The Plainwell, Otsego, and Trowbridge dams were constructed between 1899 and 1904 and subsequently decommissioned as power generators in the mid-1960s. By 1970, Consumers Power Company had transferred ownership to the MDNR. In the 1970s, water levels behind the dams were lowered. In 1985 and 1986, the superstructures of the dams were removed to their sill levels. The MDNR is considering removing the dam foundations to return part of the Kalamazoo River to run-of-river flow, to increase recreational uses and safety on the river, and to improve aquatic habitat in affected river sections (USGS 2002). The USGS is in the process of characterizing the potential impacts of the removal of the Otsego City Dam.

USGS identified one concern that might be encountered after removal of the dams: movement of the PCB-contaminated sediments and soils impounded behind the current and former dams. If the dam foundations are removed, transport and deposition of the impounded materials could alter the downstream characteristics of the stream channel and increase PCB exposure potential to stream biota (USGS 2002). It is likely that significant impacts would be observed both upstream and downstream due to the redistribution and exposure of the sediments impounded behind the dam foundations. USGS is characterizing the impoundments and evaluating the potential impacts of removing the dams.

SECTION 6

Remediation Goals

Following the drawdown of water levels in the 1960s and 1970s, the potential exposure scenario changed as in-stream sediments became an exposed floodplain soil corridor, with increased exposure-based risks from PCBs to additional human and ecological receptors. These risks are identified in the human health risk assessment (HHRA)[a] and the ecological risk assessment (ERA).[b] The risk assessments addressed the areas of Portage Creek and the Kalamazoo River referred to as the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site.

Risks and hazards are associated primarily with exposure to the PCBs that had been released into the Kalamazoo River system. The HHRA considered exposures to PCBs through ingestion of fish, direct contact with PCB-contaminated floodplain soils, and inhalation of dust and volatile emissions from floodplain soils. The results of the investigation indicate that measurable risk from exposure to PCBs is sufficient to increase cancer risk and noncancer reproductive and immunological effects. The exposures were assessed quantitatively. Accordingly, appropriate risk-based cleanup goals were established for the site.

The ERA examined the nature and extent of contamination, inventoried plants and animals that inhabit or frequent the habitats of the site, and identified threshold concentrations and criteria as they relate to the ecological system. The risk characterization, which evaluated different exposure media (e.g., floodplain soils, surface water, in-stream sediment, and fish) concluded that the primary stressor to sensitive organisms was PCBs at levels that pose ecologically significant risk. It also identified appropriate and protective cleanup levels.

6.1 Objectives

Site-specific remedial goals are established for individual media groups requiring similar or special remedial actions, based on similarities in physical characteristics of media, the nature and types of contaminants present, and the potential risk caused by exposure to the contaminated media. The Plainwell and Otsego City impoundment areas were divided into media groups: floodplain soils and in-stream sediments. Site-specific remedial goals are also based on potential exposure receptors for which protection will be provided. The HHRA and the ERA identified potential exposure routes and risks. Since risks to human health were identified, risk-based goals (RBGs) were established as the protective threshold criteria corresponding to specific carcinogenic and noncarcinogenic risks to human health.

As identified in the ERA, PCB contamination of surface water, in-stream sediments, and floodplain soils are likely to adversely affect sensitive species that inhabit or frequent the areas. Since there is risk to ecological receptors, remediation goals were established that correspond to specific effect levels and become the protective threshold criteria.

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[a] Human Health Risk Assessment

[b] *Revised Final Ecological Risk Assessment for the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site* (CDM January 2002)

Three remedial action objectives have been established for the Plainwell and Otsego City impoundment areas:

- Prevent human contact with floodplain soil contaminants that pose a total excess cancer risk greater than 1×10^{-5},[c] or a hazard index exceeding 1.[d]
- Establish and maintain a healthy and diverse ecological system in and adjacent to the impoundment areas and reduce the PCB concentrations in fish and wildlife.
- Prevent leaching of contaminants to surface water that would result in unacceptable risk to human health or sensitive ecological receptors in the impoundment areas.

6.2 Scope of Risk-Based Goals

6.2.1 Chemicals of Concern

The PCBs present in the floodplain soils of the Kalamazoo River are the primary risk drivers for the site. Therefore the remedial goals established for the site are limited to total PCBs.

6.2.2 Protection of Human Receptors

Realistic exposure scenarios are assessed to characterize potential human receptors. Residential or industrial/commercial development was not considered a realistic option since the project area consists primarily of exposed in-stream sediments and floodplain soils; thus, RBGs were not evaluated for these scenarios. The most probable human exposure to contaminated media is to a visitor who uses the river corridor for recreation.

For remediation goals protective of human health in a recreational setting, a combined pathway approach was used to reflect the total impact of exposure. The pathways used in developing RBGs included ingestion of contaminated soil, inhalation from volatilization and particulate emissions, and dermal absorption. The RBGs were established to achieve an excess lifetime cancer risk of 1×10^{-5} or a hazard index of 1.

6.2.3 Protection of Ecological Receptors

Since it is impractical to evaluate effects levels for all ecological receptors in the area, representative species known to be a part of the ecological community and to exhibit sensitivity to PCBs were chosen. The ecological receptors chosen were limited to piscivorous predators such as mink and bald eagle (fish ingestion), omnivorous birds (ingestion of invertebrates such as earthworms and terrestrial vegetation), and carnivorous terrestrial mammals such as the red fox (ingestion of prey). The ecological RBGs were established to maintain a healthy and diverse ecosystem by determining the lowest observable adverse effects level (LOAEL) and no observable adverse effects level (NOAEL) for these receptors.

[c]Acceptable carcinogenic risk established by MDEQ. USEPA carcinogenic target range is 1×10^{-4} to 1×10^{-6}

[d]Acceptable HQ established by EPA and MDEQ

TABLE 6-2
Exposure Assumptions for Risks to Recreational Visitor

Exposure Factor	Variable
Body Weight	70 kg
Exposure Time	4 hours/day
Exposure Frequency	128 days/year
Exposure Duration, Cancer Risk and Reproductive Hazard	24 years
Exposure Duration, Immunological Hazard	2 years
Ingestion Rate$_{soil/sediment}$	100 mg/day
Inhalation Rate$_{air}$	4 m^3/day
Volatilization Factor (VF)	7.3×10^{-7} m^3/kg
Particulate Emission Factor (PEF)	6.9×10^{-12} m^3/kg
Averaging Time, Cancer Risk	25,550 days (70 yr)
Averaging Time, Noncancer (Reproductive Endpoint)	10,950 days (30 yr)
Averaging Time, Noncancer (Immunological Endpoint)	730 days (2 yr)
Skin Surface Area (face, forearms, hands)	2,572 cm^2
Soil Adherence Factor	0.07
Dermal Absorption Factor	0.14

See HHRA for references.

The assumptions used for fish ingestion rates, reduction of PCBs due to cooking, and fish caught in the contaminated area differ for the central tendency and high-end sport anglers. These assumptions are presented in Section 3.5.2 of the HHRA.

The fish used to evaluate risk to sport and subsistence anglers were smallmouth bass and carp, representing top and bottom feeders. Two scenarios were evaluated for both types of anglers: ingestion of 100 percent smallmouth bass and ingestion of a combination of bass (76 percent) and carp (24 percent). To represent the range of PCB concentrations found in fish in ABSA 6, risks associated with the mean and maximum concentrations were evaluated. Table 6-3 summarizes the human health risks associated with eating fish caught within ABSA 6. As shown, carcinogenic risk from the consumption of fish caught in ABSA 6 exceeds 1×10^{-5} for all groups. Carcinogenic risk ranges from 9.0×10^{-5} to 1.1×10^{-3} for average PCB concentrations and from 3.3×10^{-4} to 3.2×10^{-3} for maximum PCB concentrations.

Noncarcinogenic HQs for the consumption of fish calculated for reproductive and immunological endpoints exceeded 1 in all groups, indicating the potential for adverse health effects. HQs ranged from 1.5 to 53 for reproductive effects and 5.3 to 190 for immunological effects.

6.3 Data Evaluation

6.3.1 Summary of Risk to Humans by Direct Contact

To quantify risk, a reasonable but conservative exposure point concentration is established that represents the target area. For the purpose of characterization, the river was partitioned into two specific target areas: one segment near the Otsego Dam, the other near the Plainwell Dam. The floodplain soils and in-stream sediments between the two dams were not looked at as a contiguous area but as two separate units. Table 6-1 lists the exposure point concentrations and associated risks for mean concentrations and the maximum detected values. The risks were based on the exposure assumptions shown in Table 6-2.

TABLE 6-1
Summary of Direct Contact Risks to Human Health

	Mean Concentration EPC (mg/kg)				Maximum Concentration EPC (mg/kg)			
Area	EPC (mg/kg)	Cancer Risk	HQ^{rep}	HQ^{imm}	EPC (mg/kg)	Cancer Risk	HQ^{rep}	HQ^{imm}
Otsego Dam*	8.4	3.6×10^{-6}	0.006	0.26	36	1.5×10^{-5}	0.26	1.1
Plainwell Dam	10.9	4.7×10^{-6}	0.008	0.34	85	3.7×10^{-5}	0.61	2.7

*Since data were unavailable for the Otsego City Dam, data for the Otsego Dam were used
EPC: exposure point concentration
HQrep: noncancer reproductive effects
HQImm: noncancer immunological effects

The HHRA estimated that cancer risk from direct contact for a recreationist in the area of the Otsego Dam range from 3.6×10^{-6} (mean concentration) to 1.5×10^{-5} (maximum concentration). Noncarcinogenic hazard quotients (HQs) from direct contact were calculated for reproductive and immunological endpoints, of which the immunological endpoint was higher. The immunological HQs for the Otsego Dam range from 0.26 to 1.1.

The cancer risk for recreationists in the area of the Plainwell Dam range from 4.7×10^{-6} for the mean concentration to 3.7×10^{-5} for the maximum. Noncarcinogenic HQs also were calculated, and the immunological HQs, again the higher of the two, range from 0.34 to 2.7.

The USEPA's target cancer risk range is 1×10^{-4} to 1×10^{-6}, and the MDEQ's target cancer risk limit is set at 1×10^{-5}. Both the USEPA and MDEQ set the acceptable hazard index at 1.

6.3.2 Summary of Risk to Humans by Ingestion of Fish

To evaluate aquatic habitats and chemical exposure, the Kalamazoo River was divided into 12 aquatic biota study areas (ABSAs). The segment of river between the Otsego City and Plainwell dams most closely correlates to ABSA 6. Information from fish captured in that area was used to evaluate potential human health risks from eating fish caught by anglers in this area. The angler population was divided into three groups:

- Subsistence anglers, who supplement their diet with sport-caught fish
- Central tendency sport anglers—the exposure to the average angling population
- High-end sport anglers—the upper-range estimate characteristic of avid sport anglers

TABLE 6-3
Risks from Ingestion of Fish from ABSA 6

Fish	Risk Type	Subsistence Angler	Sport Angler: Central Tendency	Sport Angler: High End
Average PCB Concentrations				
100% Smallmouth Bass	Carcinogenic Risk	6.7×10^{-4}	9.0×10^{-5}	2.3×10^{-4}
	HQ (Reproductive)	11	1.5	3.9
	HQ (Immunological)	39	5.3	14
76% Smallmouth Bass and 24% Carp	Carcinogenic Risk	1.1×10^{-3}	1.4×10^{-4}	3.7×10^{-4}
	HQ (Reproductive)	18	2.4	6.2
	HQ (Immunological)	63	8.4	22
Maximum PCB Concentrations				
100% Smallmouth Bass	Carcinogenic Risk	2.5×10^{-3}	3.3×10^{-4}	8.7×10^{-4}
	HQ (Reproductive)	42	5.6	15
	HQ (Immunological)	150	20	51
76% Smallmouth Bass and 24% Carp	Carcinogenic Risk	3.2×10^{-3}	4.3×10^{-4}	1.1×10^{-3}
	HQ (Reproductive)	53	7.2	19
	HQ (Immunological)	190	25	65

6.3.3 Ecological Risks

Potential ecological receptors in the Kalamazoo River area include plants and animals that may inhabit or use the aquatic, riparian/wetland, and terrestrial habitats. Several species or groups of organisms have been selected to serve as representative receptors for the detailed evaluation of potential risks presented in the ERA. These include:

- Aquatic plants
- Aquatic macroinvertebrates
- Game fish (e.g., smallmouth bass)
- Forage fish (e.g., sucker)
- Rough fish (e.g., carp)
- Terrestrial invertebrates (e.g., earthworms)
- Small burrowing omnivorous mammals (e.g., deer mouse)
- Omnivorous birds (e.g., robin)
- Semiaquatic herbivorous mammals (e.g., muskrat)
- Small semiaquatic carnivorous mammals (e.g., mink)
- Top mammalian and avian predators (e.g., red fox, great horned owl, bald eagle)

6.3.4 Ecological Impacts Identified in the ERA

Most aquatic biota, such as invertebrates and fish, are unlikely to be affected adversely by direct contact with and ingestion of surface water because of the relatively low PCB toxicity to most aquatic biota (not including bioaccumulation of PCBs).

Floodplain sediment and surface soil contaminated with PCBs may pose risk to terrestrial and semiaquatic biota, depending on life history (e.g., foraging behavior, diet, mobility) and sensitivity to PCBs. Such risk is considered to be low to moderate, depending on species. Omnivorous terrestrial species (represented by mice) are unlikely to be at significant risk unless they reside in the most contaminated areas. PCB uptake in mice appears to be low.

PCB contamination of floodplain soils is likely to affect the following sensitive ecological receptors adversely:

- Omnivorous birds
  - **Robins** may be at risk if they consume substantial amounts of soil invertebrates, such as earthworms.
- Piscivorous predators
  - **Mink** may be at risk through consumption of PCB-contaminated prey, especially fish. The most likely effects are impaired reproduction and subsequent decrease in mink populations. Current evidence suggests that mink populations are declining.
  - **Bald eagles** may be at risk through consumption of fish and foraging in contaminated areas.
- Carnivorous terrestrial mammals
  - **Red fox** may be at some risk from foraging in PCB-contaminated areas and the consumption of prey that reside in those areas.
- Carnivorous birds
  - **Great horned owl** may be at significant risk, depending on diet. The actual diet of the great horned owl in the Plainwell and Otsego City impoundment areas is uncertain, but food web modeling suggests low risk.
- Semiaquatic herbivorous mammals
  - **Muskrat** may be at risk because estimated dietary doses exceed recommended threshold values for rats, assuming that rats and muskrats are equally sensitive to the ingestion of PCBs.

6.4 Risk-Based Goals

6.4.1 Human Health RBGs

The RI determined that soil within the Plainwell and Otsego City impoundment areas is contaminated with PCBs and poses a potential risk to human health. Since the remedial action objective for the floodplain soils is to prevent exposure to soil contaminants at levels resulting in unacceptable risk, remediation goals based on human health were established. This process differs from the risk assessment process in that it projects a level of contamination required to achieve an acceptable target cancer risk—in this case 1×10^{-5} or a noncancer hazard index of 1.0. As with the HHRA, the process is limited to chemicals for which carcinogenic slope factors and noncarcinogenic reference doses (RfDs) are available. Table 6-4 lists the slope factors and RfDs used in the risk assessment and in establishing RBGs.

The risk-specific concentrations presented do not represent a determination of "safe" floodplain soil and sediment conditions. They are estimates based on specific exposure assumptions and risk levels using current toxicity information. Since toxicity values are subject to change, health-based PRG exposure concentrations are also subject to change. The exposure concentrations are for PCBs only and do not account for exposure to other chemicals that may be present.

Based on the risk process described above, RBGs goals were established to protect recreationists exposed to contaminated floodplain soils by ingestion, dermal contact, and inhalation. Table 6-5 summarizes the human health RBGs for PCBs.

TABLE 6-4
Toxicity Values for PCBs (slope factors and RfDs)

SFo	SFi	RfDo Immunological Effects	RfDo Reproductive Effects
2.0	0.4	0.00002[a]	0.00007[b]

All measurements in mg/kg/day
SFo: Carcinogenic Slope Factor, oral, upper bound
SFi: Carcinogenic Slope Factor, inhalation, upper bound
RfDo: Noncancer Reference Dose, oral

a. Based on Aroclor-1254 (immune system decreased antibody)
b. Based on Aroclor-1016 (reproductive effects, reduced birth weights)

TABLE 6-5
Human Health RBGs for PCBs

Risk	RBG (mg/kg)
1×10^{-4} Cancer Risk	230
1×10^{-5} Cancer Risk	**23**
1×10^{-6} Cancer Risk	2.3
Noncancer Effects, Reproductive Endpoint	**139**
Noncancer Effects, Immunological Endpoint	**32**

6.4.2 Ecological RBGs

The PCB-contaminated soils within the Plainwell and Otsego City impoundment areas also pose risk to ecological receptors known to inhabit or frequent the site. Since the remedial action objectives for the floodplain soils are to establish and maintain a healthy and diverse ecosystem in and adjacent to the impoundment areas, RBGs have been established to protect sensitive ecological receptors. The proposed cleanup ranges include no-effect levels at the lower end and low-but-significant effect levels at the upper end. Table 6-6 lists the protective RBG PCB ranges for the representative species.

TABLE 6-6
Risk-Based Goals for Ecological Receptors

	NOAEL-based RBG	LOAEL-based RBG	Based On
In-stream Sediments (aquatic and semiaquatic organisms)	0.3 (mg/kg)	0.6 (mg/kg)	Mink
Floodplain Soils (terrestrial ecological systems)	**1.6 (mg/kg)**	**8.1 (mg/kg)**	**Songbirds (robin)**
	5 9 (mg/kg)	29.5 (mg/kg)	Carnivorous mammals (red fox)

The most sensitive species within the ecological system of the Otsego City Dam and Plainwell Dam impoundment areas are the mink for in-stream sediments and the songbird (robin) for floodplain soils.

6.4.3 Discussion on Calculating Robin-based RBGs

The threshold reference value (TRV) is a dietary effect dose that represents no- or low-effect doses of a particular chemical for a receptor organism. For nonraptors such as American robin exposed to PCBs, it is difficult to determine the most appropriate no- and low-effect TRVs because of significant differences in methodologies and study designs. The result is questionable levels of confidence in the NOAEL dose. Therefore an alternative to selecting a single NOAEL or LOAEL was used to determine the no- and low-effect TRVs for nonraptor birds.

No- and low-effect TRVs are based on the effects of PCBs on chickens, which have been extensively studied. The low-effect TRV, which was based on Aroclor-1248—the principal PCB congener found in earthworms in the Kalamazoo River floodplain—is 0.5 mg/kg/$_{BW}$-d. The calculated no-effect TRV for birds is 0.1 mg/kg/$_{BW}$-d, also based on Aroclor-1248.

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The formula that was used to calculate the BRGs for PCBs using the no- and low-effect TRVs is:

PRG = (NOAEL or LOAEL TRV / Dose) × Soil PCB[e]

The average daily dose ("Dose" in the above formula) is the amount of chemical intake that occurs on a daily basis. The average daily dose was calculated to be 0.9044 mg/kg-d, by using the equation

Dose = (NIRww × Worm PCB × DFworm) + (NIRww × Veg PCB * DFveg) + (NIRdw × Soil PCB × DFsoil) [f]

where:

NIRww	=	normalized ingestion rate, wet weight (0.89 kg/kg body weight-day)
Worm PCB	=	PCB concentration for worm (1.314 mg/kg)
DFworm	=	dietary fraction for worm (0.51)
Veg PCB	=	PCB concentration in terrestrial vegetation—fruit (0.00168 mg/kg)
DFveg	=	dietary fraction for terrestrial vegetation—fruit (0.49)
NIRdw	=	normalized ingestion rate, dry weight (0.2074 kg/kg body weight-day)
Soil PCB	=	PCB concentration in floodplain soils (14.6 mg/kg PCB used)
DFsoil	=	dietary fraction—floodplain soils (0.1 used)

Another approach presented in the ERA to determine the RBC for robins incorporates the bioaccumulation factor (BAF) :

PRG = NOAEL or LOAEL TRV / ([NIRww × BAFworm × Dfworm] + [NIRww × BAFveg × DFveg] + [NIRdw × DFsoil])[g]

where:

BAFworm	=	bioaccumulation factor for worm (0.09 wet weight/dry weight)
BAFveg	=	bioaccumulation factor for vegetation (0.0008 wet weight/dry weight)

[e] Table 5-5 of the ERA

[f] Table C-2-A of the ERA

[g] Section 4, page 24 of the ERA.

RBGs protective of the robin were determined to be 1.6 mg/kg (no effect) and 8.1 mg/kg (low effect).

6.4.4 Discussion on Calculating Mink-based RBGs

It is difficult to determine the most appropriate no- and low-effect levels for mink exposed to PCBs because their diet encompasses a variety of aquatic, semiaquatic, and terrestrial animals, resulting in uncertain exposure scenarios. Thus, a different approach was used to determine RBGs for mink. No- and low-effect TRVs were determined by interpolating the effective dietary concentration based on exposure-response curves.[h] The low-effect level is 75 percent of the control response for a toxicological endpoint, based on Aroclor-1254, which is the most toxic to mammalian receptors. The no-effect TRV, based on Aroclor-1242 which has a narrow range between the no effect and low effect TRVs, is one-half that for Aroclor-1254.

The mink RGBs are based on dietary thresholds protective of mink that consume PCB-contaminated fish. The dietary thresholds are 0.3 mg/kg (no-effect) and 0.6 mg/kg (low-effect). The first step was to calculate the surface water threshold.

$$SW_{threshold} = (\text{TRVmg PCB/kg fresh weight diet/BAF}) \times 1000_{\text{Conversion Factor}}$$

The sediment RBG was then calculated from the $SW_{threshold}$

$$SW_{threshold} \times \text{Surface water-to-sediment Partition Factor}/1000_{\text{Conversion Factor}}$$

For a discussion on food web and food chain modeling and RBG determinations of other potential ecological receptors, refer to Section 4 of the Revised Final ERA.

6.5 Conclusions

Table 6-7 summarizes the final RBGs for all receptor groups. For floodplain soils, the RBG is 1.6 mg/kg (NOAEL) to 8.1 mg/kg (LOAEL) to be protective of the robin. To be protective of mink, the RBG for in-stream sediments is 0.3 mg/kg (NOAEL) to 0.6 (LOAEL) mg/kg PCB.

TABLE 6-7
Summary of Final Risk Based Goals

Receptor Group	Media	RBG (mg/kg)	Comment
Recreational Visitor	Floodplain Soils	23	Cancer effects at 1×10^{-5} cancer risk level for ingestion, inhalation, dermal pathways
Carnivorous Mammal (mink)	In-stream Sediments	0.3 to 0.6	From the consumption of fish
Omnivorous Birds (robin)	**Floodplain Soils**	**1.6 to 8.1**	**From the consumption of worms and terrestrial vegetation**

[h] See the "Revised Final Ecological Risk Assessment" for discussion

SECTION 7

Summary

This report addresses the floodplain soils in two impounded reaches within OU-5 of the Allied Paper/Portage Creek/Kalamazoo River Superfund Site, designated the Plainwell and Otsego City impoundments by the USEPA's Fully Integrated Environmental Location Decision Support (FIELDS) group. It will support the FS in evaluating alternatives to eliminate, reduce, or control risk to human health and the environment from the floodplain soils in the two impoundments. The goal of the RI and FS is to produce reports that will lead to the development of a well-supported Record of Decision (ROD).

7.1 Nature and Extent of Contamination

Chemical compounds that have been detected in the floodplain soil samples from the Plainwell and Otsego City impoundments include PCBs, VOCs, SVOCs, pesticides, dioxins, and metals (including mercury). The primary contaminants of concern in the Kalamazoo River are PCBs. Total PCB concentrations in the floodplain soils of both impoundments range from not detected to 158 ppm, with an average of 5.5 ppm. Average PCB concentrations in the floodplain soils of the Plainwell impoundment (7.8 ppm) are significantly greater than those of the Otsego City impoundment (1.6 ppm). The median PCB concentrations are 0.70 ppm for the Plainwell impoundment and 0.09 ppm for the Otsego City impoundment.

A trend of decreasing PCB concentrations with increasing depth below the surface is observed in the floodplain soils of both impoundments. The highest average PCB concentrations typically are detected in the top 12 inches of floodplain soil with elevated PCB concentrations (> 5 ppm) typically confined to the upper 12 to 24 inches of soil.

In the Otsego City impoundment, the highest PCB concentrations are encountered at two distinct locations. The highest concentrations are found just upstream of the Otsego City Dam. A plume of decreasing PCB concentration with distance from the 12th Street Landfill is evident within the upper 24 inches, indicating that the landfill was a potential source of PCBs to the floodplain soils. Below 24 inches, little PCB contamination is present in the Otsego City impoundment. In the Plainwell impoundment, PCB concentrations show a relatively uniform concentration gradient throughout the reach. Elevated PCB concentrations are fairly uniform within the surficial layer (0 to 6 inches) of floodplain soils and decrease with depth.

The total PCB mass is estimated to be 6,656 pounds in the Otsego City impoundment and 5,097 pounds in the Plainwell impoundment. However, the PCB mass in the Otsego City impoundment is contained in a soil volume more than four times as great as that within the Plainwell impoundment (1.3 million cubic yards versus 0.3 million cubic yards).

7.2 Fate and Transport of PCBs

PCBs released into the Kalamazoo River have accumulated in the sediment bed of the river and the adjacent floodplains. Sources of the PCBs in the Kalamazoo River include both point and nonpoint sources. The presence of PCBs has been documented in sediments as far upstream of the Plainwell impoundment as Morrow Lake.

The Kalamazoo River has been affected by numerous former and existing dams that slowed the flow velocity upstream of the dams. The impounded areas upstream of the dams that had been submerged by the river water acted as depositional areas for the PCB-contaminated sediments that the river transported from upstream areas. Sediment deposition behind the Plainwell and Otsego City dams accounts for much of the PCBs in areas of the floodplain that were previously below water.

Following the drawdown of water in the Otsego City impoundment in the 1960s and the Plainwell impoundment in the 1970s, some sediments impounded behind the dams were transported downstream due to increased river flow velocity. Much of the impounded area, however, remained in place. Many of the impounded areas were exposed during the drawdown of the water levels behind the dams. Previously inundated sediment was exposed as the water levels behind the dams were lowered. The exposed areas now comprise much of the floodplain soils.

Another primary mechanism believed to account for the presence of PCBs in the floodplain soils is inundation of the floodplain when river flow is high. When flow is high, the PCB-containing sediments become suspended in the water column and transported downstream. Water that contains PCBs (both dissolved and adhering to suspended solids) often overflows the riverbanks onto the adjacent floodplain (i.e., inundation of the floodplain during high river flow periods), depositing the contaminated sediments on the floodplain soils.

Some PCBs in the floodplain soils have arrived during high flow events following the drawdown of water levels in the 1960s and 1970s. The lowering of the water and the demolition of the superstructures of the Plainwell Dam between 1985 and 1986 resulted in the erosion, transport, and redistribution of instream lacustrine sediments that had been impounded behind the dam (USGS 2002). Upon the drawdown of water levels behind the dams and the removal of the Plainwell Dam to its sill, a large flow of river water containing sediments formerly impounded behind the dams likely flushed downstream. Some of the water overflowed the riverbanks to the adjacent floodplain, depositing the PCB-containing sediments on the floodplain soils.

After the river was lowered, flow velocities in the Kalamazoo River increased and quickly carved a new channel into the soft sediments behind the dams, leaving steep banks consisting of the newly formed floodplain soil. The depositional areas in the impoundments became soil erosional areas, with hundreds of acres of newly exposed sediments constituting the floodplains. The floodplain soil banks in some areas have been and remain susceptible to undercutting, erosion, and downstream transport due to increased river velocities, decreased side-slope stability, and potential channel meandering (BBL 2000a).

The observation of erosion of the floodplain soils in the river, combined with laboratory results that show that the floodplain soils contain PCBs, confirm that the banks of the river continue to act as a source of PCBs (BBL 2000a). Erosion of the riverbanks results in the downstream transport and redistribution of PCB-containing soils. Once floodplain soils containing PCBs enter the river's water column, they are transported in suspension or as bed load to downstream areas by river currents.

Other transport processes for the PCBs in the floodplain soils include desorption to the interstitial pore water, leaching to groundwater, volatilization into the atmosphere, biodegradation, and uptake by plants and animals. PCBs are not water soluble, are moderately volatile, are resistant to biodegradation, and once released to the environment have an affinity for (and typically partition to) the organic matter in soil, sediment, and biota. The fate and transport of PCBs are related primarily to the adsorption to soil or sediment particles or other organic matter. The PCBs adsorbed on the solid particles are transported predominantly within the environment by the physical processes that transport the solid particles. Therefore, these transport processes are not likely to be significant loss mechanisms for PCBs in the floodplain soils within the impoundments.

Although previous reports have documented the presence of ongoing natural processes that are reducing PCB levels in other environmental media, this has not been observed in the floodplain soils based upon the current PCB data. Evaluation of the floodplain soil data showed that PCB concentrations in floodplain soils have remained relatively unchanged or may have increased in some cases. No trends of increasing or decreasing PCB concentrations were apparent when data from all depth intervals between 1993 and 2001 were compared. PCB concentrations in the upper 6 inches of floodplain soil show an increase in the same period, suggesting a potential continuing source of PCBs to floodplain soils. However, this observed trend may be attributable to different targeted sampling areas and sampling objectives of the individual investigations.

7.3 Human and Ecological Risks

The human health and ecological risk assessments provided a conservative estimate of the potential for risk to public health and local ecological populations by the presence of PCBs in floodplain soils and in-stream sediments. Toxicity values and toxicological endpoints for site contaminants were identified from standard USEPA sources. The results show that PCBs present the most significant risk to humans and sensitive members of the ecological community.

In performing the ecological risk assessment, the nature and extent of contamination was evaluated, an inventory of plants and animals near the river was made, and threshold concentrations and criteria as they relate to sensitive ecological populations were examined. The exposure media (floodplain soils, surface water, in-stream sediment, and fish) were examined, and toxicological endpoints for site contaminants were assessed. It was concluded that PCBs pose the primary risk. Risk characterization, which combines toxicity values with estimated doses, yields an estimated level of risk to specific members of the ecosystem in and adjacent to evaluated area. The represented ecological population includes aquatic organisms such fish, piscivorous predators such as mink and bald eagle, omnivorous birds such as American robin, and carnivorous terrestrial mammals such as red fox.

The greatest risk to human health from exposure to PCBs is through the ingestion of fish caught in the river. Ecological receptors are affected primarily through the food web. The ecological population, which is far more sensitive to the effects of PCBs under the evaluated exposure scenarios, is the foundation for the proposed cleanup goals for floodplain soils.

7.4 Data Gaps

Important information that may be necessary to evaluate further the risk to the Kalamazoo River system posed by the PCBs contained in the floodplain soils of the Plainwell and Otsego City impoundments are either unavailable or insufficient. Data gaps include erosion rate estimates within the Otsego City impoundment area, groundwater PCB data, and congener-specific PCB data to evaluate the possibility of ongoing biodegradation processes.

SECTION 8

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